

**Dr. Dobb's Journal of**

#113 MARCH 1986  
\$2.95 (3.95 CANADA)

# Software Tools

FOR THE PROFESSIONAL PROGRAMMER

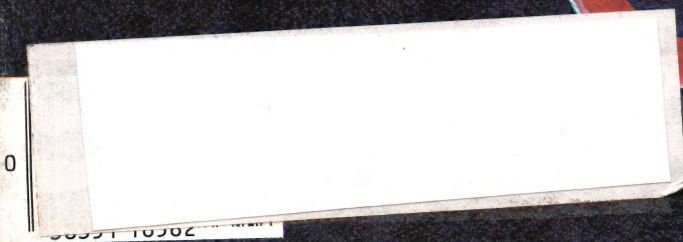
## PARALLEL PROCESSING

Concurrency and  
Turbo Pascal

What makes  
DOS fast?

Minimizing arbitrary  
functions

MC68000 vs. NS32000







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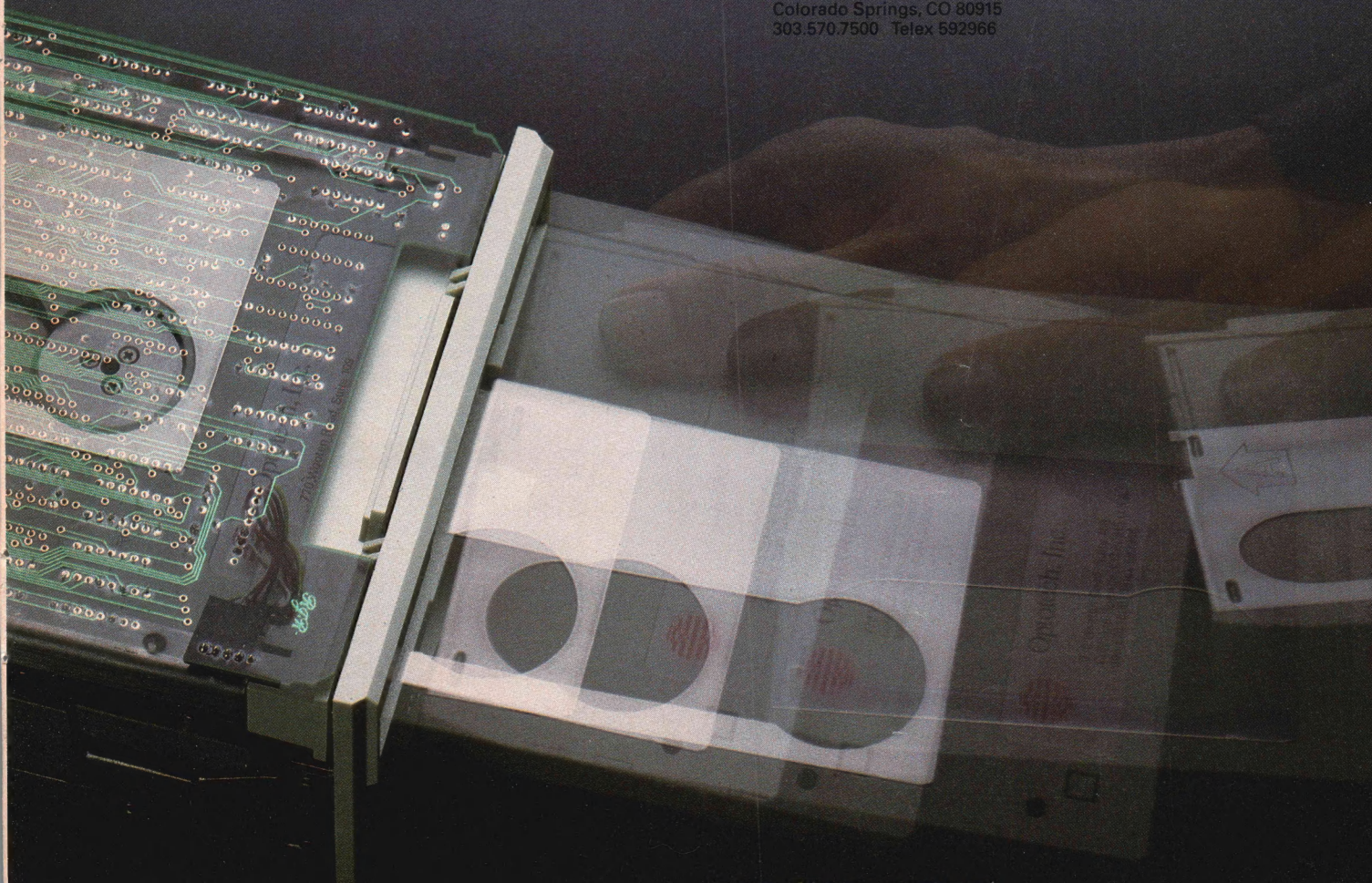
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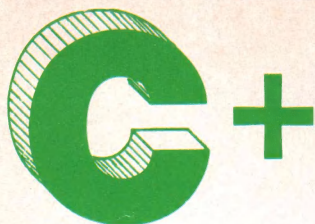


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abs  
asm  
asmx  
atan  
atoi  
atol  
bdos  
bdosx  
bios  
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calloc  
ceil  
cfree  
chain  
character  
chdir  
chmod  
clearerr  
close  
clrscrn  
cmpstr

conbuf  
conc  
cos  
cpyst  
creat  
curblk  
curbln  
curcol  
cursrow  
cursoff  
curson  
delete  
drand  
exec  
exec1  
execv  
exit  
exitmsg  
exp  
fabs  
fclose  
fdopen

feof  
ferror  
fflush  
fgets  
fileno  
filetrap  
find  
floor  
fopen  
fprintf  
fputs  
fread  
free  
freopen  
fscanf  
ftell  
fwrite  
getc  
getch  
putc  
getchar

## Functions

getcseg  
getdseg  
getd  
putd  
getdate  
gettime  
geti  
puti  
getkey  
getmode  
setmode  
gets  
getw  
heapsiz  
heaptrap  
hypot  
index  
inp  
insert  
iofilter  
isalnum  
isalpha

isascii  
iscntrl  
isdigit  
islower  
isprint  
ispunct  
isspace  
isupper  
itoa  
keypress  
left\$  
len  
log  
log10  
longjmp  
lseek  
malloc  
alloc  
mathtrap  
mid\$  
mkdir  
modf

movmem  
open  
outp  
peek  
perror  
poke  
poscur  
pow  
printf  
putc  
putchar  
puts  
putw  
rand  
read  
readatr  
reach  
writech  
readdot  
writedot  
realloc  
rename

replace  
repem  
rewind  
right\$  
rindex  
rmdir  
scanf  
setbuf  
setcolor  
setdate  
settime  
setjmp  
setmem  
sin  
sound  
sprintf  
sqrt  
srand  
sscanf  
stacksiz  
str\$

strcat  
strncpy  
strcpy  
strlen  
strncat  
strncmp  
strncpy  
strsave  
system  
tolower  
toupper  
ungetc  
ungetch  
unlink  
write  
writechs  
xmembeg  
xmemend  
xmemget  
xmemput  
xmovmem  
\_exit

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100 predefined commands. The editor comes configured so that it works just like Wordstar but you can change it if you prefer a different keyboard layout. The editor is a great companion to our C compiler. Because they work so well together we want you to have both. To make sure you do, we're offering the editor for just \$15 when purchased with the C compiler.

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**Dr. Dobb's Journal of**  
**Software Tools**

## ARTICLES

**Warping space  
for minimum  
benefits** ▶

**MATH: A Variable Metric Minimizer** 24  
*by Joe Marasco*  
 Unconstrained minimization seeks the minimum of a function regardless of its form: polynomial, transcendental, or weird.

**Teaching tasks  
to share** ▶

**PASCAL: Concurrency and Turbo Pascal** 36  
*by Ernest E. Bergmann*  
 Coroutines are an important feature of Modula-2 and Ada; here is a straightforward approach to implementing coroutines in Turbo Pascal.

**FUTURE PROGRAMMING: The Problems of Parallelism** 40  
*by Michael Swaine*  
 Will the future be parallel?

**MS DOS: Speeding MS DOS Execution** 44  
*by Gregg Weissman*  
 Inspired by Dave Cortesi's puzzles regarding MS DOS execution speed, the author interrogated the operating system for the solution.

**PORTABILITY: Automatic Porting Between Pascal Dialects** 50  
*by Michael J. Sorens*

**If it's Tuesday,  
this must be  
Turbo.** ▶

This article presents a proven technique for automating the task of porting your programs from one Pascal to another.

**PORTABILITY: COM: An 8080 Simulator for the MC68000** 108  
*by Jim Cathey*  
 Listing of Cathey's program continued from January

## COLUMNS

**A new column  
on assembly  
language** ▶

**C CHEST: The Last of the Shell Support Routines** 14  
*by Allen Holub*

Allen wraps up the DOS shell with the last of the support routines.

**THE RIGHT TO ASSEMBLE: Square Roots on the NS32000** 122  
*by Richard Campbell*

National Semiconductor's 320XX processors were designed with high-level language compilation in mind. Code and benchmarks in C and 320XX assembly language show some interesting differences.

## FORUM

PROGRAMMERS'  
SERVICES

**What's up on  
the DDJ SIG** ▶

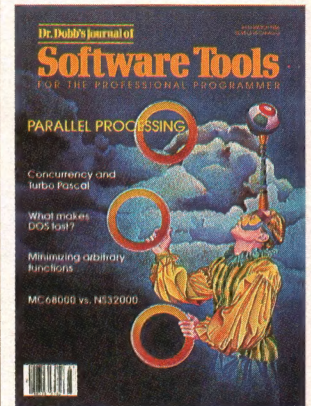
**EDITORIAL: Sharing** 6  
*by Michael Swaine*

**LETTERS: Comment** 8  
*by you*

**CARTOON: Parallel Processing** 8  
*by Rand Renfroe*

**OF INTEREST: New products of interest to programmers** 124

**ADVERTISER INDEX: Where to find that ad** 128



## About the Cover

Parallel processing. Like a juggler whose right hand is better off not knowing what the left is doing, one starts the various processes going and trusts the rhythm of the task to stave off disaster. The cover illustration was done by Tim Gault of Gault Design and Illustration.

## This Issue

The advent of parallel processing could force us to rethink the way we solve problems. Mathematical algorithms in general are routinely, almost by implicit definition, sequential. Now, things are changing. Is some new Knuth writing the book on parallel algorithms? Herein, some perspective on parallel processing today and an example of concurrency in Pascal. Also please note the new column on assembly language and Joe Marasco's monumental minimizer.

## Next Issue

Our annual look at the techniques of artificial intelligence will present code in Prolog, LISP, and Expert-2, led off by Bob Brown's BRIE (Boca Raton Inference Engine).



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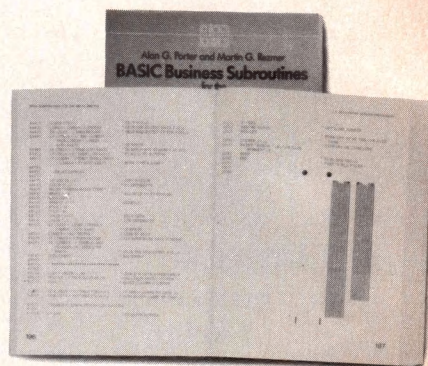
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## THE ADVANTAGES OF TURBO PASCAL AND DATA STRIPS

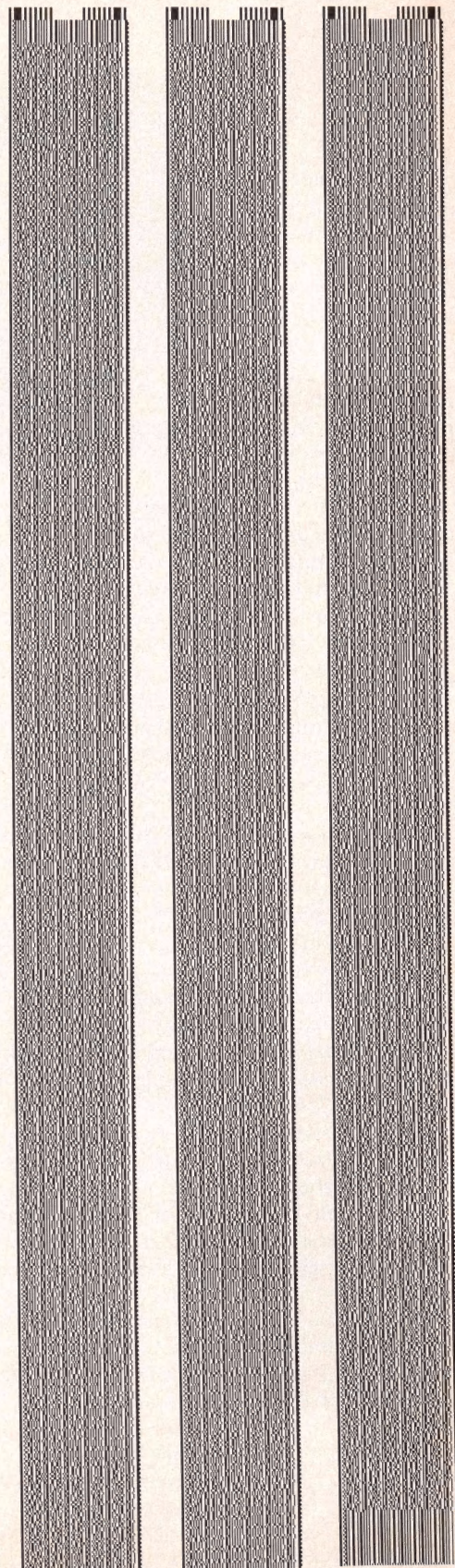
The Cauzin Softstrip™ data strips, on the right, contain the problem described in the article "Concurrency and Turbo Pascal" in this issue.

As you'll recall, Ernest Bergmann, after much trial and error, came up with a means to use Turbo Pascal (CP/M-80) for implementing several concurrent tasks. The techniques are useful for writing software that has to respond to several real-time events, such as a modem program.

As Mr. Bergmann points out: because of the ease of writing and trying variations quickly and clearly, Turbo Pascal is an ideal and convenient way to become acquainted with multi-tasking.

After you've read in the data strips, refer to Mr. Bergmann's article for operating instructions.

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1|

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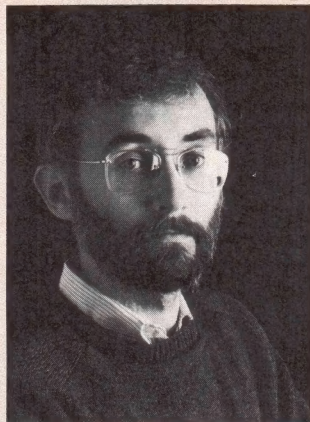


# EDITORIAL

**A**dmirers of the late, lamented *Softtalk* PC will experience a twinge of déjà vu on reading our table of contents this month: The Right to Assemble was a regular feature of that magazine, written by our own Ray Duncan. The writer in us regretted such an apt title going to dust, and the programmer in us wanted to see a regular column on assembly language in our pages, so the editor in us made some phone calls. Craig Stinson of *Softtalk* and Ray graciously granted us use of the title. The column's contents will come from several authors and address several architectures; it will always include assembly-language code.

It's hard to let a good column title or idea atrophy. We got a call from Fred Davis at *A+* magazine asking of us what we had asked of Craig and Ray. As a result, Computer Calisthenics, the puzzle column launched here in *DDJ* by Michael Wiesenbergs, is now running in *A+*. Many of you will recall that the original complete title of *DDJ* was *Dr. Dobb's Journal of Computer Calisthenics and Orthodontia: Running Light Without Overbyte*. Now we just need to license the Orthodontia.

The real old-timers will be grumbling about our error in the last paragraph; the original title spoke of *Tiny BASIC*, not *Computers*, they will point out. True enough, and that's occasion for another note of avuncular pride: Gordon Brandly's February 1985 piece entitled "Tiny BASIC for the 68000" was just reprinted in *I/O*, a leading Japanese computer magazine. *I/O* has also reprinted Jim Hendrix's articles on Small-C. We're happy that *DDJ* can be involved in software development worldwide. In fact, since we believe that the community of serious programmers



is fundamentally one international community, we are beginning to make a greater effort to distribute the magazine internationally and to draw on authors from around the world.

This issue was too stuffed to fit in Chip-

Watch, Professional Programmer, or *DDJ* On Line, but here at least is the on-line report:

After a fitful start in January, the *DDJFORUM* is humming along nicely on CompuServe. We apologize to all who logged on January 1 only to find things in an unfinished state. We became fully operational on January 16 and since then have gradually added to our Data Libraries (DLs). You can now download all the code from issues 111, 112, and 113 (with the exception of Allen Holub's MS DOS shell and utilities) along with various selections from back issues.

We want the DLs to contain listings that our readers have asked for. If there is something from a back issue that is particularly useful to you, let us know. If demand is great enough, we will make it available.

Our message boards have also seen considerable activity. Columnists Ray Duncan and Allen Holub are sycops and log on regularly to answer queries and chat. As of the date this was written, no special conferences have been planned, but we suggest that you sign on and read the Conference Bulletin to find a more recent update.

Hope you will drop by soon.

*Michael Swaine*

Michael Swaine

Dr. Dobb's Journal of

## Software Tools

### Editorial

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Address correction requested. Postmaster: Send Form 3579 to *Dr. Dobb's Journal*, P.O. Box 27809, San Diego, CA 92128. **ISSN 0884-5395**

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# The C for Microcomputers

PC-DOS, MS-DOS, CP/M-86, Macintosh, Amiga, Apple II, CP/M-80, Radio Shack, Commodore, XENIX, ROM, and Cross Development systems

## MS-DOS, PC-DOS, CP/M-86, XENIX, 8086/80x86 ROM

### Manx Aztec C86

*"A compiler that has many strengths ... quite valuable for serious work"*

Computer Language review, February 1985

**Great Code:** Manx Aztec C86 generates fast executing compact code. The benchmark results below are from a study conducted by Manx. The Dhrystone benchmark (CACM 10/84 27:10 p1018) measures performance for a systems software instruction mix. The results are without register variables. With register variables, Manx, Microsoft, and Mark Williams run proportionately faster, Lattice and Computer Innovations show no improvement.

	Execution Time	Code Size	Compile/Link Time
Dhrystone Benchmark			
Manx Aztec C86 3.3	34 secs	5,760	93 secs
Microsoft C 3.0	34 secs	7,146	119 secs
Optimized C86 2.20J	53 secs	11,009	172 secs
Mark Williams 2.0	56 secs	12,980	113 secs
Lattice 2.14	89 secs	20,404	117 secs

**Great Features:** Manx Aztec C86 is bundled with a powerful array of well documented productivity tools, library routines and features.

Optimized C compiler	Symbolic Debugger
AS86 Macro Assembler	LN86 Overlay Linker
80186/80286 Support	Librarian
8087/80287 Sensing Lib	Profiler
Extensive UNIX Library	DOS, Screen, & Graphics Lib
Large Memory Model	Intel Object Option
Z (vi) Source Editor -c	CP/M-86 Library -c
ROM Support Package -c	INTEL HEX Utility -c
Library Source Code -c	Mixed memory models -c
MAKE, DIFF, and GREP -c	Source Debugger -c
One year of updates -c	CP/M-86 Library -c

Manx offers two commercial development systems, Aztec C86-c and Aztec C86-d. Items marked -c are special features of the Aztec C86-c system.

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<b>Aztec C86-d Developer's System</b>	<b>\$299</b>
<b>Aztec C86-p Personal System</b>	<b>\$199</b>
<b>Aztec C86-a Apprentice System</b>	<b>\$49</b>

All systems are upgradable by paying the difference in price plus \$10.

**Third Party Software:** There are a number of high quality support packages for Manx Aztec C86 for screen management, graphics, database management, and software development.

<b>C-tree \$395</b>	<b>Greenleaf \$185</b>
<b>PHACT \$250</b>	<b>PC-lint \$98</b>
<b>HALO \$250</b>	<b>Amber Windows \$59</b>
<b>PRE-C \$395</b>	<b>Windows for C \$195</b>
<b>WindScreen \$149</b>	<b>FirstTime \$295</b>
<b>SunScreen \$99</b>	<b>C Util Lib \$185</b>
<b>PANEL \$295</b>	<b>Plink-86 \$395</b>

## MACINTOSH, AMIGA, XENIX, CP/M-68K, 68k ROM

### Manx Aztec C68k

*"Library handling is very flexible ... documentation is excellent ... the shell a pleasure to work in ... blows away the competition for pure compile speed ... an excellent effort."*

Computer Language review, April 1985

Aztec C68k is the most widely used commercial C compiler for the Macintosh. Its quality, performance, and completeness place Manx Aztec C68k in a position beyond comparison. It is available in several upgradable versions.

Optimized C Macro Assembler	Creates Clickable Applications
Overlay Linker	Mouse Enhanced SHELL
Resource Compiler	Easy Access to Mac Toolbox
Debuggers	UNIX Library Functions
Librarian	Terminal Emulator (Source)
Source Editor	Clear Detailed Documentation
MacRam Disk -c	C-Stuff Library
Library Source -c	UniTools (vi, make, diff, grep) -c
	One Year of Updates -c

Items marked -c are available only in the Manx Aztec C86-c system. Other features are in both the Aztec C86-d and Aztec C86-c systems.

<b>Aztec C68k-c Commercial System</b>	<b>\$499</b>
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## LETTERS



## Columns

Dear DDJ,

I noticed an apparent error in the listing of `fgrep.c` in DDJ, September 1985. The fifth line on page 63 should read `stoupper(str);` not `-stoupper(buffer);`. This would keep the `-y` flag from working unless a string file was used.

Michael J. Eager  
481 Century Dr.  
Campbell, CA 95008

Dear DDJ,

I got a red Dr. Dobb's T-shirt at the Journal's CP/M 82 (or was it 81?) booth. Now, alas, I need another piece of apparel to go with it: a black armband with the words "Bring Back Cortesi."

The old guard keeps changing at Dr. Dobb's. Nostalgia for the chip-smoking-hackers' glorious Portola Valley tabloid can't mask the fact that times are a changing out here for your readers too. No one cares anymore whether we can redirect PUN: to a solder-on UART. They care whether the shirt is white. Thank Peter Norton they don't care whether the collar is buttoned!

Losing Cortesi is another matter. He was current. He was relevant. He was beautifully articulate. And though I'd rather give up night skiing than Turbo Pascal, he was most often right.

Good luck, Dave, pursu-

ing whatever "interest having nothing to do with software" you're into.

Charles Landis  
1803 39th Ave. East  
Seattle, WA 98112

## ProDOS

Dear DDJ,

I have been receiving DDJ in exchange for another publication, which has gone down the tubes. For the past six months I have glanced at your magazine. Undoubtedly, I would not have renewed my subscription. With the December 1985 issue, however, you have captured my attention. Imagine finding two articles pertaining to the Apple II world and, more particularly, to ProDOS, my favorite subject. If such events continue, I might become a disciple or even a contributor. What are DDJ's plans for addicts like me? How about an is-

sue devoted to the 6502?

It would be out of character for me not to comment on Shawn Day's article, "Adding a Copy Command to ProDOS." I have several nits to pick and one severe deficiency to point out.

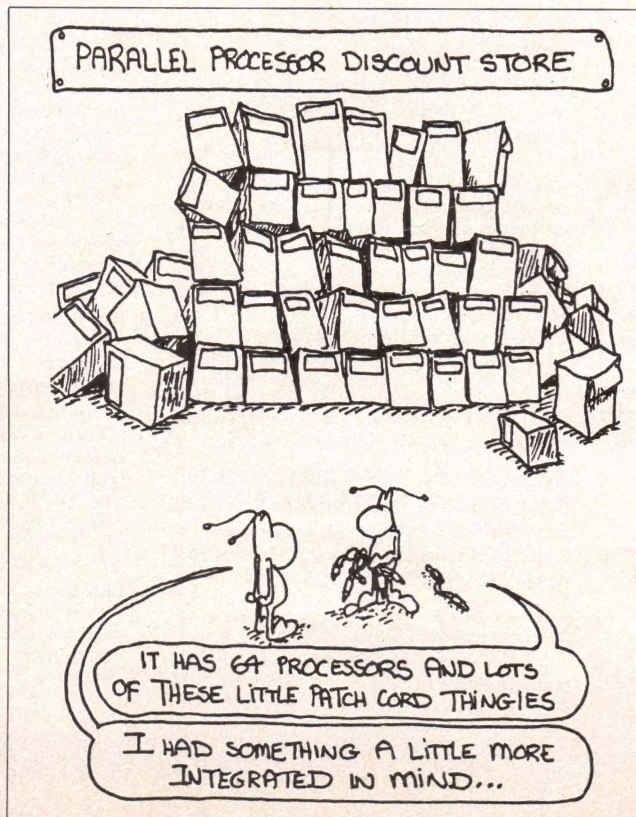
In first stage processing, a pointer is used for reading the text of the user's input from the primary text buffer. This could have been accomplished more directly by examining the input buffer. In keeping with ProDOS BASIC convention, spaces should have been ignored during command parsing. Finally, it is not necessary to implement prefix fetching and file creating in PBITS. If you doubt this assertion, assign values of 3 and 0 to PBITS and PBITS+1, respectively, and observe that program function does not change.

In second stage process-

ing, every direct call to the machine-language interface could be replaced by a call to GOSYSTEM, making program size smaller and program logic more consistent. This fault is minor, however, in comparison to the inability of the code (e.g., lines 361-378) to copy sparse files accurately. Before describing a solution to the problem, I shall briefly explain this generic file entity.

A sparse file contains discontinuous data (i.e., holes exist in the file). The number of data bytes that potentially can be read from the file exceeds the number of data bytes actually stored within the file. A random access text file (RATF) is the prototypical sparse file. Not all RATFs are sparse, but the potential exists. For example, consider a RATF with a record length of 512 bytes. One physical ProDOS block holds one file record. When you first open (i.e., create) the file, it has a length of 0 and is contained on one block. If next you write 10 bytes of data to Record 200, the file length becomes 102,410 bytes (i.e.,  $10 + [512 \times 200]$ ) but the file occupies only three blocks. If all of the prior records held data, the file would require 202 blocks. Thus, the file is sparse. This economy of space is made possible by index blocks which keep track of but do not allocate space for dataless records. Under ProDOS the most extreme example of this phenomenon is a file whose length is 16 megabytes and whose physical size is only 5 blocks. That's sparse!

When Shawn Day's code reproduces a sparse file, it assigns physical blocks to actual and potential data





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## LETTERS

(Continued from page 8)

blocks alike. Using my first example, his copy command would produce a file with 202 blocks instead of 3 blocks. That is not acceptable, especially since RATFs almost cry out to be copied to a RAM disk. What to do?

The principles involved in correcting the flaw are not difficult. When a file is opened, the buffer reserved for that file is 1024 bytes long. The lower half holds an image of the most recent data block being read or written. The upper half contains an image of the index block for the current 128K of file content. By reading the source file in one-block increments, checking whether data exists by testing the corresponding index bytes (e.g., zero means no data; non-zero indicates data), and writing to the target file only if data is found, the sparse file can be faithfully duplicated. File position must be monitored during the process so that data is written to the correct location within the target file. The SET\_MARK and GET\_MARK commands are ideal for this purpose. Admittedly, block-by-block transfer of file contents is slower than bulk movement, but the difference in speed is surprisingly small for files of 64K or less, and accuracy is the sine qua non for a file copy program.

If any reader would like an annotated listing of this process, I shall be happy to provide one for the price of a SASE.

Let's hear it for the 6502!  
Sandy Mossberg  
50 Talcott Rd.  
Rye Brook, NY 10573

### Bose-Nelson Sort

Dear DDJ,  
Mr. Celko's article on the

Bose-Nelson sort (DDJ, September 1985) was very interesting and thought-provoking, particularly his comments on stable versus nonstable sorts. As an addendum to his article, I wish to offer the following remarks:

1. I was unable to get the recursive program (Listing One) to work. There appear to be at least two problems. First, in the procedure *boresort*, the test *if(n>1)* is incorrect since *n* has not been declared. I suspect that this test should be *if(j>1)*. Second, the expression for *m* simplifies to *m=j/2*. This cannot be correct since the result is an endless sequence of recursive calls *boresort(2,2)*. Since the notation used in Listing One is different from the notation used in the algorithm statement (an unfortunate choice!) I

cannot deduce how *m* should be calculated.

2. As printed, Listing Two is also incorrect. In case 2 of procedure *boresort*, the first call to *push3* should instead be a call to *push5*. Also, in case 3, *x* is defined twice. The second definition should be *y = stack[top-4]*.

3. To compare the recursive and nonrecursive methods, I wrote the program shown in my Listing One, page 54, (borrowing heavily from Mr. Celko's Listing Two!). Note that my method of retrieving command line arguments is applicable to Small-C.

4. For some reason, the sequence of swaps generated by the recursive program is the reverse of the sequence produced by the nonrecursive version.

5. A brief comparison of the recursive version (my

Listing One) with the non-recursive version (his Listing Two) is shown in Table 2, below. Execution times have been corrected for loading time. Also, the timed programs did not print out the swap pairs.

6. The B-N algorithm generates 32,708 pairs for a list of 664 items. Therefore, if you must sort more than this many items, you must either use an unsigned integer for the variable count, or you must use a longer integer.

7. Table 1, below, compares the B-N sort with the theoretical minimum and with  $n \log_2(n)$  for values of *n* up to 40. A few points should be noted. First, the B-N sort efficiency drops off fairly steadily as *n* increases. For *n*=100, the B-N algorithm generates almost three times the minimum number of swap pairs. However, the relationship is not smooth. For example, increasing from 95 to 96 items requires 7 additional swaps. Increasing to 97 items requires 64 additional swaps, and increasing to 98 items requires 32 additional swaps.

8. I have not had a chance to test the B-N strategy against the more popular sorting algorithms. Obviously, a B-N sort will take less time to sort a sorted or nearly sorted list (fewer swaps are required) than a random list. However, if we compare the number of swap pairs generated by the B-N algorithm with  $n \log_2(n)$ , as shown in Table 1, it appears that for large values of *n* (say, 15 or higher) a Bose-Nelson sort may not be able to compete with a properly selected conventional sort.

Richard J. Wissbaum  
15553 E. Wyoming Dr. - H  
Aurora, CO 80012

DDJ

n	Theory	B-N	$n \log_2(n)$	n	Theory	B-N	$n \log_2(n)$
1	0	0	0	21	66	118	93
2	1	1	2	22	70	125	99
3	3	3	5	23	75	133	105
4	5	5	8	24	80	138	111
5	7	9	12	25	84	154	117
6	10	12	16	26	89	163	123
7	13	16	20	27	94	173	129
8	16	19	24	28	98	179	135
9	19	27	29	29	103	191	141
10	22	32	34	30	108	198	148
11	26	38	39	31	113	206	154
12	29	42	44	32	118	211	160
13	33	50	49	33	123	243	167
14	37	55	54	34	128	260	173
15	41	61	59	35	133	278	180
16	45	65	64	36	139	288	187
17	49	81	70	37	144	308	193
18	53	90	76	38	149	319	200
19	57	100	81	39	154	331	207
20	62	106	87	40	160	338	213

**Table 1:** Comparison of Bose-Nelson Sort with Theoretical Minimum

	Recursive	Non-Recursive
.EXE file size	8633	14166
Execution Time (100 items)	1.3	2.6
Execution Time (1000 items)	54.6	110.9

**Table 2**



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## VIEWPOINT

## Shrink-wrapped Big Macs?

I read with great interest the editorial in the December 1985 *DDJ* concerning the recent spate of litigation in the software industry. I share the concern expressed regarding current trends in software protection and in particular with how many software publishers are claiming both copyright and trade secret protection for software packages that are widely distributed.

As an attorney specializing in patent, trademark, copyright, and other intellectual property law, I have always believed that patents should protect underlying ideas, and copyrights should protect the expression of ideas. The United States Supreme Court has clearly shown that a patentable invention exists even when the actual improvement exists solely in software. Consequently, if a programmer develops a software package that performs new and useful functions then the idea underlying the software may be patentable.

On the other hand, Copyright Statute 17 USC, (Section 101, et seq) specifically provides that copyright protection for an

original work of authorship does not protect "any idea, procedure, process, system, method of operation, concept, principle, or discovery, regardless of the form in which it is described, explained, illustrated, or embodied in such work."

The National Commission on New Technological Uses of Copyrighted Works (CONTU), empowered by Congress to review copyright legislation, concluded that copyright protection should be afforded to computer programs and databases. It proposed changes in the copyright statute, including a provision stating that it would not be an infringement for a rightful possessor of a copy of a computer program either to use the program in conjunction with a machine or to make archival copies.

It is interesting that this section (Section 117) as enacted does not use the language "rightful possessor" but rather uses "owner of a copy." Although I have not been able to find any legislative history concerning the change, it is clear to me that the party or parties who caused this change were mindful that the owner of a copyrighted work may license the use of a copy of the copyrighted work as distinguished from selling a copy of the work. Therefore, if one could argue that what would normally be considered a sale of a copy was instead a license to use a copy then all bets would be off with respect to the aforementioned section and to Section 109(a) of the copyright law. Section 109(a) states that the owner of a particular copy is entitled, without the authority

of the copyright owner, to sell or otherwise dispose of the possession of that copy.

Although a license can certainly be entered into between two parties, it requires more than the opening of a package to show acceptance of terms of the license; it is also outside the intention of CONTU that trade secrets be preserved by licensing copies wherein hundreds or thousands of licenses are made in such a manner. The software subcommittee report from CONTU states that it is self-evident that trade secrecy cannot be relied upon if a program is widely marketed or otherwise broadly distributed.

Some software publishers have been trying to have their cake and eat it too. They claim to have copyright protection and are only granting licenses to use copies of the copyrighted work, such licenses being accepted by the user opening a package. By their reasoning, virtually any item, not just software, could be packaged in a shrink-wrap form containing a "license" limiting all warranties, liabilities, and even ownership of the item! Certainly that was not the intention of CONTU and was an oversight by Congress when the phrase "rightful possessor" was changed to "owner of a copy."

I am in the process of investigating this matter further and may recommend that legislation be introduced to amend Section 117 of the Copyright Statute. A change in the statute is the proper avenue to clarify the right of the purchaser of a computer program to make archival copies and to analyze the

program. If the publisher wishes to protect underlying inventive ideas it should seek such protection by way of the patent statutes, which provide protection for a 17-year term in exchange for full disclosure of the invention. I would appreciate comments and thoughts because any change should be supported by all interested parties seeking to have fair protection afforded the authors of computer programs.

DDJ

### Alfred A. Fressola

*Alfred A. Fressola is a partner in the Law Offices of Mattern, Ware, Stoltz, & Fressola P.C., 34 Sherman Ct., P.O. Box 783, Fairfield, CT 06430. He is also a member of the Computer Law Section of The Connecticut Bar Association.*



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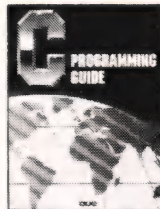
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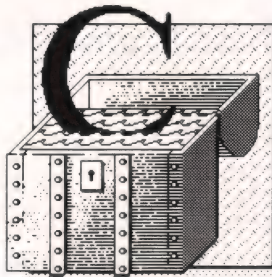
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## The Last of the Shell Support Routines



The code this month is the last of the shell support routines. A few subroutines are useful enough as stand-alone library routines to mention here, but for the most part I'll let the code speak for itself.

*Ssort()* (Listing Ten, page 70) is another general-purpose sort routine modeled after the Unix *qsort()* routine (See C Chest, April 1985). The April column implemented the routine as a Quicksort, whereas this version uses an adaptation of the Shell Sort in K & R. For many applications (especially those with only a small amount of data to sort or those where the data has already been sorted) a Shell Sort is a better way to go than a Quicksort. It uses much less code, and for small *N*, it's about as efficient as Quicksort. Like *qsort()*, *ssort()* is passed four arguments—the base address of the array to be sorted (*base*), the number of elements in the array (*nel*), the width of one element in bytes (*width*), and a pointer to a comparison function that is passed pointers to two elements in the array and should otherwise work like *strcmp()* does. You can find more details on how to use this routine and on how a shell sort works in the April C Chest.

*Reargv()* (Listing Nine, page 68) is not so much part of the shell itself as a routine for other programs that are being run under the shell. It's passed pointers to *argv* and *argc*, and it replaces these with another version created from the CMDLINE environment variable generated by the shell when a command is executed. The shell's complete (up to 2,048-byte) command line is passed to a program using this mechanism, because you

that the program name is available as *argv[0]* if you use *reargv()*. This is not the case in DOS Versions 1 or 2.

If possible, you should incorporate the code from *reargv()* directly into your root module (where it belongs). It's provided here as a separate function because the Microsoft compiler doesn't give you the root module sources, so you have no choice but to call an independent subroutine.

*Dir()* (Listings Seven and Eight, pages 56 and 57) is a modified version of the directory routines that were part of the *ls* directory utility given in the July C Chest. *Dir* is passed a pointer to an initialized structure (called a *DIRECTORY*) containing various commands. It gets a directory and puts it into an *argv*-like array of pointers to strings, part of this structure. *Mk\_dir()* creates a *DIRECTORY* structure. You set various flags in the structure to tell *dir()* what to do and then call it with a file specification and a pointer to the initialized *DIRECTORY* as its arguments. When the subroutine returns, various fields of the *DIRECTORY* will have been updated to hold the proper file or subdirectory names as well as other information such as file sizes and a volume label. The returned directory is sorted for you (using *ssort()*). The routine *del\_dir()* deletes a *DIRECTORY* structure. *Dir.h* (Listing Seven) has details about how to initialize the *DIRECTORY* and how *dir()* modifies it. If you want to see an example of how *dir()* is used, look in the shell on lines 478–566 of Listing One (January 1986). Refer to the July C Chest for details about getting directories from DOS in general.

*Dir* works in slightly different

ways from the *ls* described in July. The major difference is the total file size. If you specify a long format listing, the file size in bytes is still listed as part of the *dirv* entry. This size is the number of actual characters in the file. The total byte count, however, reflects the number of bytes actually occupied by the file on the disk. In DOS the minimum number of bytes allocated to a file is a "cluster," which is a contiguous group of disk sectors. On the PC/AT hard disk, a cluster requires 2K (four 512-byte sectors); 2K are required to store a file, even if that file contains only one character. The totals returned by *dir()* will reflect the file sizes, rounded up to the cluster size for your particular disk. (It varies from disk type to disk type—1K clusters are used on a 354K double-sided floppy.)

### Lvalues

A few months back I mentioned a problem I was having with the Lattice C compiler. In particular, I wanted to be able to say:

```
long   x;
int    *p;

x = *(long *)p)++;
```

in order to be able to fetch a long-size object pointed to by *p* and then increment *p* as if it were a pointer to *long*. Lattice kicks this code out with an "lvalue required" error message. The code:

```
long   x;
char   *p;

x = *(long *)p;
p += sizeof(long);
```

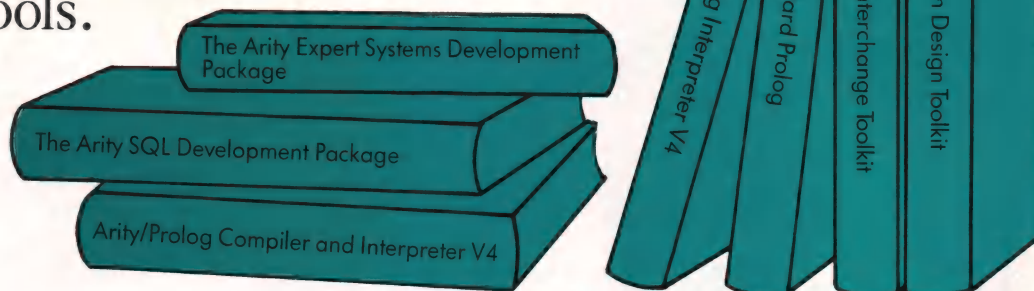
is accepted by Lattice. I think the first expression ought to compile, and in support of my contention, several compilers do indeed accept the statement and generate the correct code:

by Allen Holub

can pass only 127 characters via DOS. *Reargv()* should be called before *argv* or *argc* are used in *main()*. Note



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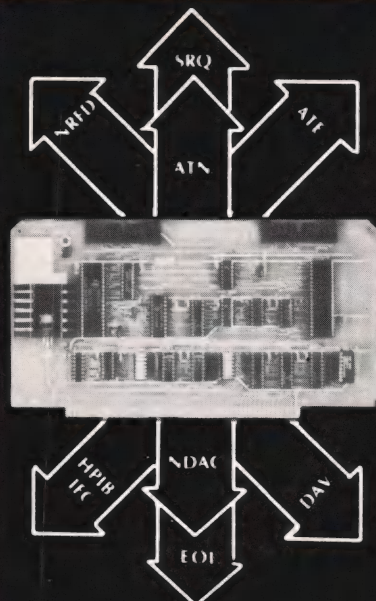
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### C CHEST (Continued from page 14)

Microsoft C (Version 3.0), Aztec C (Version 3.20d), and Whitesmith's C for the 68000 are three of these. Jim Howell writes that the Introl C compiler for the 6809 also generates correct code. Jim also mentions that the C-systems C compiler outputs garbage but doesn't report an error.

Several people have written about this problem, most of them advancing the argument that the Lattice C compiler is behaving rationally. In order to understand the problem better, we should start by defining *lvalue*. K & R say: "An *object* is a manipulatable region of storage; an *lvalue* is an expression referring to an object. An obvious example of an *lvalue* is an identifier. There are operators that yield *lvalues*: for example if E is an expression of pointer type, then \*E is an *lvalue* expression referring to the object to which E points. The name '*lvalue*' comes from the assignment expression E1=E2 in which the left operand E1 must be an *lvalue* expression."<sup>1</sup>

So, an *lvalue* is the place where the results of an expression evaluation are stored. As J. S. Williams writes, however, an "*lvalue* is not just an expression on the left-hand side of an assignment statement. A better interpretation is that the *lvalue* of an expression is the symbolic location of the value of the expression." That is, it's an address into which the result of the expression evaluation will be put. An *lvalue* has to be a real place—a variable that's been declared somewhere or the place pointed to by a pointer.

Several people mention a complementary concept to an *lvalue*—an *rvalue*. An *rvalue* represents the value of an *lvalue*. That is, if an *lvalue* is the address into which we'll put the result of an expression, an *rvalue* is the result itself—the number that will be put into the *lvalue*. Consulting the grammar in Appendix A of K & R (pages 214–219), there's no nonterminal symbol called an *rvalue*. That is, the concept of *rvalue* can be used to describe several nonterminal symbols in the grammar, whereas an *lvalue* is actually a nonterminal. Thus, talking about *rvalues* might help us to understand the problem conceptually, but the *rvalue* is not bolted

into the language as is the *lvalue*.

Nevertheless, an *rvalue* is a useful concept. The creation of an *rvalue* may involve memory allocation over which you have no control. Compilers sometimes put intermediate results of an expression evaluation into scratch variables (or registers) that they allocate transparently to your program. Thus, an *rvalue* may be associated with an "anonymous temporary" variable that you cannot access directly.

Wayne Throop writes, "A cast is defined in K & R (page 42) like this: 'In the construction "(type-name) expression," the expression is converted to the named type by the conversion rules above. The precise meaning of a cast is in fact as if the expression were assigned to a variable of the specified type, which is then used in place of the whole construction.' Now, this paragraph can possibly be interpreted to mean that a cast must be an *lvalue*. Most compilers, however, do not so implement it. The key is in the 'converted to the named type' phrase. A cast (potentially) changes the bits of the cast expression. Anonymous temporaries are normally not treated as *lvalues* because things assigned to them can never be retrieved later."

In other words, a cast generates an *rvalue*, and as a result of evaluating the cast, the number might be copied into a scratch variable in order to ease any necessary arithmetic manipulation associated with the type conversion (such as sign extension, truncation of high-order bits, and floating point to integer conversion). So, in

```
x = *(long *)p)++;
```

the  $(\text{long}^*)p$  may cause  $p$  to be copied to a temporary variable as part of the cast operation, and the  $++$  would increment the temporary variable, not  $p$  itself.

The point about temporary variables is well taken. Nevertheless, just because it's easiest for the compiler to always put a cast variable into an anonymous temporary, this behavior is not required by the language. More to the point, just because a variable might be copied somewhere else, there's no reason why the compiler can't copy it back when it has fin-



ished with it. In any event, *p* doesn't have to be copied anywhere in the problem we're discussing. We don't need to modify it; *long* pointers and *int* pointers are the same physically. The difference lies in how the object pointed to is used, not in any dissimilarities between the pointers themselves. By the same token, if *p* isn't copied to a temporary variable, there's no reason why you can't increment it, and several compilers will indeed let you increment a cast pointer.

To my mind, the human being shouldn't have to do something (or not do something) for the convenience of the compiler; rather, the compiler should do its best to behave rationally, provided that the input is rational. A compiler that makes intelligent decisions about when to copy and when not to copy variables is a better compiler—there's no point in copying objects that don't need to be copied. Unfortunately, many compilers—and Lattice C seems to be one of these—don't operate intelligently.

As a footnote, a more technically correct argument against incrementing a cast variable is that there's no obvious way to parse such an expression using the formal grammar in the back of K & R. Because several compilers accept the construct, it's obviously possible to write a grammar in which incrementing a cast variable is acceptable. More to the point, the grammar in K & R isn't used "as is" in any C compiler that I know of. Everybody (including K & R) has modified it a little to make it more realistic when they write a real compiler. The grammar in my copy of the draft proposed ANSI standard bears little relation to the one in K & R, so until the ANSI standard is formalized, I don't think the grammatical argument is valid either.

There is one argument that I do think is valid. As I've learned the hard way,  $x = *((long*)p)++$  is not portable, at least it's not portable to Lattice. On the other hand,  $x = *((long*)p); p += sizeof(long)$  is acceptable to all compilers. This second method is therefore preferable for portability reasons.

### Problems with The Microsoft C Compiler

A few months ago Microsoft sent me

a review copy of the new version (3.0) of its C compiler. I've been using it since then (to develop the shell I've been talking about since January, among other things).

I really want to like this compiler. It generates compact code, and its implementation of the language is one of the best I've found (it supports enumerated types and strong type checking à la the proposed ANSI standard). Moreover, its library documentation is organized quite nicely, with all the functions in alphabetical order instead of grouped by function (a prac-

tice I never could understand). You can find the documentation for any routine in the library quickly just by looking it up. There's no need to consult a cross-reference, then an index, and then look it up. Microsoft has tried to minimize the number of functions described by a single entry (very little of the one-page-for-15-similar-functions business), and every entry has a See Also section and an Examples section. I wish every compiler's library documentation was organized as nicely as Microsoft's.

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The library is one of the more complete that I've seen, too, especially in the operating system support area. For example, it has both a *getenv* and a *putenv* routine so you can not only retrieve a variable from the current environment but you can add a variable to it as well. *Putenv* lets you pass variables to a spawned process pretty easily, without having to go through a temporary file. The compiler also comes with a Unix-like ver-

sion of the cc driver program. (It can compile and link your source code in one step.)

Unfortunately, the compiler itself has several serious problems. Like most compilers, the Microsoft compiler is actually several programs that are invoked in sequence by a controlling driver program. The various programs communicate with each other via temporary files and the command line. The first things I tried to compile were the hyphenation routines from October's C Chest column, and the compiler wouldn't

do it. Pass 3 of the compiler kicked out an incomprehensible error message that referred to a line number in a temporary file that was erased by the driver program (or so I assume—the file was not to be found on the disk). So, I thought to myself, I'll just run the passes by hand instead of letting the supplied driver program do it for me. No good. The individual passes of the compiler are not documented—anywhere. You can't run them yourself. More to the point, were I a naive user the situation would be more incomprehensible because the documentation doesn't explain that compilation involves the invocation of programs that you know nothing about. Anyway, I eventually fixed the problem by stripping the large arrays of initialized data out of the offending file and putting them into a second file. The compiler's problem seems to have something to do with symbol table space overflow, but who knows?

Another related problem—the compiler lets you use several environment variables to pass it information. The INCLUDE environment, for example, can hold a list of places to look for #included files. It seems, however, that the driver program knows about these environments, but the other programs that make up the compiler do not. In particular, the driver program passes the contents of the INCLUDE environment to the subprograms using the DOS command line. The DOS command line is limited to 127 bytes, so if the INCLUDE environment has too many characters in it, the command line can be truncated and the invoked subprogram will spit out an incomprehensible error message. Again, this behavior is not documented. You are not told to limit the length of the INCLUDE environment.

The above problems are characteristic of a general nonchalance toward error processing on the part of Microsoft. The compiler's normal error processing, even when it's working properly, is among the worst I've ever seen. Its error messages are for the most part uninformative and error recovery is nonexistent. For example, the message

"Syntax error '{' "

was generated by a missing semico-

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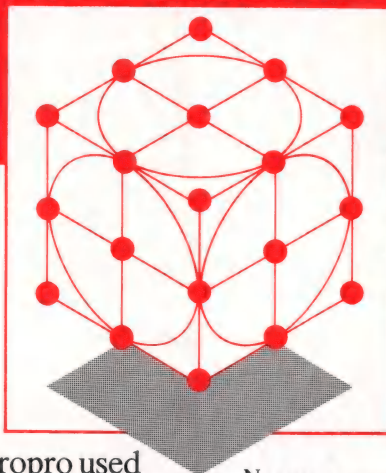




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lon several lines above the one that was flagged in the error message. The compiler is showing you the symbol following the semicolon, the one that confused it. Because a missing semicolon is perhaps the most common error in a C program, you'd think that Microsoft would at least handle this one carefully—but no. Semicolons weren't mentioned in any of the hundred spurious error messages that followed. (I'm not ex-

aggerating the number of messages either, there really were a hundred of the things.) And then, to add insult to injury, the compiler aborted, telling me that there were too many errors to continue processing even though the missing semicolon was the only real error in the file.

This sort of behavior is repeated with disgusting regularity. A missing semicolon, colon, parenthesis, or curly bracket is a disaster. Misspell a keyword, and all is lost. Spurious error messages are a serious problem in themselves, and they can't be

eliminated entirely, but a well-designed compiler ought to be able to recover from an error within a few statements and then go on processing. At the very least, it could skip to the next subroutine declaration and then start processing from there (you can do that with a regular expression). As far as I can tell, though, the Microsoft compiler makes no attempt to recover.

These goings-on dramatically slow a program's development time. Instead of compiling, fixing five or ten errors, and then recompiling, I have to compile, fix only one error, compile again, fix one error, and so forth. I may have to recompile 10 or 15 times to get all the errors fixed, a very time-consuming process to say the least. I don't care how fast a compiler is, if I have to recompile 15 times to find 15 errors, I'll never finish my program.

Another real problem here is the error message not telling me what the error was. If I were not already a reasonably proficient C programmer, I'd never have found some of my errors (which were sometimes several lines above the one flagged by the error message). If you don't already know C very well, the Microsoft compiler is a waste of money. You'll get so disgusted with its behavior, you'll never learn the language well enough to debug any but the simplest program.

Another problem is that the documentation doesn't mention various important differences between the way a Microsoft library routine works and the way that the equivalent Unix routine works. The most serious of these problems that I've found so far is in the *spawn* function. It turns out that files opened by a parent process are closed when the child process terminates! (And I don't use the *! lightly*.) It seems OK for a child to inherit copies of the parent's file descriptors (which is documented), but the child shouldn't be able to modify them, much less close them. Even worse, it is an *exit*( ) call in the child that does the closing, not an explicit call to *close*( ). In other words, there is no way for a file to stay open after a child is spawned. Maybe this isn't a problem with the *spawn* function at all, maybe it's a bug in MS DOS. In any event, bug or not, this aber-

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rant behavior should be documented. There isn't a word about it in the manual, and it took me half a day to track it down.

There are a few other inconsistencies (such as *strncpy* pads out the string with nulls to the maximum count—why?), but I won't go into all of them here. The compiler also has several, more minor problems—for example, it ignores the last line of a file if it isn't terminated with a new line. An *#endif* without a *CR* gives an "unexpected end of file" message. The library function *fgets()* doesn't have this bug in it—why does the compiler?

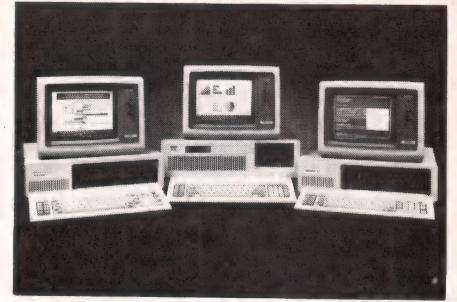
Though the library documentation is nicely done, the *User's Guide* is awful. It has very little discussion of unfamiliar, Microsoft-specific parts of the language. This lack of detail is made more intolerable because the *User's Guide* spends thousands of words talking about topics with which most readers will be familiar. For example, on page 25 it says: "It is recommended that you create a separate directory for each type of file. . . . (Refer to your MS-DOS documentation if you are unfamiliar with the procedures for setting up and maintaining directories)." Does Microsoft seriously believe that a C programmer doesn't know how to set up a directory? Another example is on page 36 where we find a long treatise on how to create a batch file: "You can create an MS-DOS batch file to set up the compiler environment and invoke the compiler. Creating and using batch files is discussed in full in your MS-DOS manual. This section is intended simply to demonstrate possible uses of the *MSC* command in a batch file . . ." and on, and on, and on. The manual talks about how to use batch files for the rest of the page and most of the next. Most readers don't need to be told what a batch file is ad nauseam; those who don't know can find the material in the DOS manual. In fact, the *User's Guide* could be shortened by about 50 percent if it started out with the sentence: "This manual assumes that you are familiar with MS DOS. If you are not, please read your MS DOS documentation before proceeding." Why make readers wade through pages of useless verbiage to find the few buried pieces of real informa-

tion and then not provide them with adequate information when a new topic is introduced?

Worse than this garbage is the lack of real information on many obscure or hard-to-understand parts of the Microsoft C implementation. The keyword *far*, for example, is used to create a 32-bit pointer in a small model program; but the user's manual gives you almost no information, and no examples whatsoever, on how this keyword should be used. I tried for about half an hour to declare a *typedef* for a far pointer to an unsigned object before I hit on the right combination of keywords. The manual was no help and neither were the error messages, most of which said "syntax error" and little else. I don't mind Microsoft's introducing a new keyword, especially one as useful as this one, but it should be documented up the wazoo. It is not.

One final problem and then I'll quit. It's impossible (or rather, so hard that I don't want to bother) to make either ROMable code or .COM files with the Microsoft compiler. In the course of my normal consulting work, I have to write a lot of ROMable code. To do this with most compilers, you need a copy of the C root module so that you can modify it to do your system initializations. You also need a special root module if you want to make .COM files. Lattice and Aztec both provide the root module source with their compilers. Microsoft does not. When I called Microsoft to ask about getting a copy, the staff were pretty reluctant even to talk about it. Finally I managed to talk to Sandra Jacobson, the VP in charge of C product marketing, and she told me that the root source was available but that it cost \$500 (that's five hundred—two zeros after the five). This left me speechless for a moment—\$500 is more than the compiler costs. For \$500 Manx gives you two compilers (one optimizing, the other not); the complete source code for the entire I/O library, not just the root module; copies of several Unix utilities (*grep*, *ls*, *make*, *diff*, and a version of the *vi* editor); an assembler; a linker; and several other utilities. Where does Microsoft get off asking \$500 for 100 lines of code, without which their compiler is useless to anyone who has to put a program into ROM? The

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## C CHEST

(Continued from page 21)

only response I got was that not many of its customers require it. Well, I require it. The company wasn't sympathetic. Then it said that another reason for not releasing the root module is that it didn't want to provide user support for it—the module was “too complex” and Microsoft “wasn't too proud of the way that the program looked.” To

my mind, this doesn't speak well for the quality of Microsoft's programming or of its support. If Microsoft can't explain the internal workings of its own compiler, who can? It seems that it'll only provide support if your question isn't too hard. To all appearances Microsoft has gone the way of several large corporations: “We don't care, we don't have to.”

In conclusion, the Microsoft C compiler is a good implementation of the C language, with a very complete I/O

library and laudable library documentation. It generates compact code and is easy to use (once you wade through the *User's Guide*). As far as I can tell, the code it produces is error-free. Because of serious flaws in the error recovery mechanism, however, an extremely poorly written *User's Guide*, and a certain reticence on Microsoft's part to really support its own product, the compiler is useless to anyone who is not already a very experienced C programmer and to anyone who has to generate ROMable code or do serious systems programming. Though the library documentation is well organized, it is opaque, not telling you anything about the internal workings of the routines. There's no way (short of disassembling the library) to make ROMable code or .COM files with the Microsoft compiler. Even if you're an experienced programmer, I'm not sure you'd be willing to put up with the awful error recovery, which is bound to slow up your development time, or spend inordinate amounts of time trying to figure out how a library routine works and what undocumented bugs it contains.

As I write this, a copy of the Manx Aztec C 86 compiler has just arrived in the mail and a copy of Lattice, Version 3, is on the way. I'll report back sometime in the next few months, after I've had a chance to use them for a while.

### Shell Availability

This column is part of a four-part series describing the entire shell. A reprint of all four parts along with a disk containing the listings and an executable version of the shell are available for \$29.95 from *Dr. Dobb's Journal*, 2464 Embarcadero Way, Palo Alto, CA 94303. Please see the advertisement on page 71.

### Note

1. Kernighan & Ritchie, *The C Programming Language* (Englewood Cliffs, N.J.: Prentice-Hall, 1978), 183.

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(Listings begins on page 56.)

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# A Variable Metric Minimizer

by Joe Marasco

**T**his article describes a variable metric minimizer, a program that finds the set of parameters to a function that will produce the smallest output value from that function. Minimization is a common problem in many fields. A familiar exam-

ple of this process is the least squares fitting of a set of data to a straight line. Here, an explicit set of equations is used to derive the optimal value for the slope and the intercept of a straight line that approximates the input data. (The minimized function is the sum of the squares of the deviations of the data points from the straight line.) That is, least squares fitting finds the equation of the line that goes as closely as possible through the middle of a set of data points. Of course these points have to be linelike to begin with; forcing randomly scattered data into a line has no meaning.

The least squares function, because it's using lines, requires you to find two parameters (the slope and the intercept). To fit a parabola rather than a line to your data, you'd have to find three parameters instead of two. In general, polynomial fitting for a degree  $n$  polynomial requires you to find  $n + 1$  parameters.

But you need not limit yourself to polynomials. Your data might fit a more exotic combination of powers, such as a rational fraction or a continued fraction. It might also

*The program does unconstrained minimization in  $n$  dimensions by looking at the global topology of the problem as well as local information from the derivatives.*

contain terms with trig, log, or other transcendental functions. In general, we'd like to be able to find the minimum for any function, regardless of the complexity. All data can't be meaningfully depicted as a straight line.

When no limits are put on the parameters to a function, we have an "unconstrained" minimization problem in  $n$  dimensions (where  $n$  is the number of parameters that can vary). Imagine an  $n$ -dimensional surface; our problem is to find the "lowest" point on the surface. As you might expect, this process can be both difficult and time consuming. The "search space" becomes very large as the dimension of the problem increases. By the late 60s and early 70s, the general minimization problem was brought under control on large mainframe computers for functions of about 10–20 parameters. Today methods exist for handling much larger problems, but these are not really amenable to microcomputer implementation.

The program presented here uses methods now accepted as both robust and efficient. That is, these methods can handle a wide variety of functions and data without failing, and they can find a minimum in a shorter period (fewer iterations) than other methods. Some methods seek minima by a sort of "curve crawling." Like the proverbial drop of water, they tend to smell "down" and go in that direction.

The steepest descent method, for example, looks at the local topology (read: derivative information) and points itself orthogonally (at right angles) to the level curves in an effort to point toward the minimum. The process is

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clarified by thinking of a contour map of a volcanic crater. Just below the rim, the contour map will show a series of concentric circles. The program looks at this map, points itself toward the center by finding a direction at a right angle to a contour line, and off it goes. There are other considerations in a real problem. For example, how big a step do you take? (You don't want to go up the other side.) You get the idea though. The spacing of the contour lines will help you with step size.

Of course this example is a bit contrived. Many geometries aren't concentric circles. The contour lines may often look like wickedly curved and contorted bananas, making the program waste a lot of time going toward the minimum. Think of a meandering river: It's always going downhill. At each point it is locally following the largest gradient. Nevertheless, when viewed from above, the river doesn't follow the shortest path from the top to the bottom.

The methods I have used are called "quasi-Newton positive definite secant update" methods. The "variable metric" part comes from looking at the global topology of the problem in addition to the local information given by the derivatives. That is, we're looking at the river both from above and from the perspective of the river itself. These methods try to take bananalike contours and transform coordinates internally so that they appear to the algorithm as concentric circles. Because the "metric" for doing this transformation changes as we move about, the methods are called variable metric methods. These methods converge more rapidly to the minimum than do other approaches.

Davidon seems to have been the first person to hit on these methods. The Davidon-Fletcher-Powell (DFP) method is still one of the best algorithms available. A similar method—the Broyden-Fletcher-Goldfarb-Shanno (BFGS) method—is thought to be somewhat superior for some problems. These two methods have survived lots of empirical testing, and most people consider them to be the best. Both methods are used in the accompanying program as well as a "steepest descent" method for comparison's sake.

A word of caution: All these methods have some limitations. They all tend to find a local minimum, but over the hill there may be a deeper valley. Your local minimum may not be the global minimum. Hence these methods may depend somewhat on where you start them. The better your original estimate of where the minimum might be, the better chance you have of not getting stuck in the wrong one when there are multiple minima. Unfortunately, in higher dimensions it's often difficult to guess how many minima there might be or where they might be. Saddle points can be troublesome too, fooling the program into thinking that it has arrived at the minimum. This difficulty is compounded as you use higher dimensions.

## Theory

This section describes briefly how the minimizer works so that you can follow the code. The description is pretty meaty; you may want to skip past it if the mathematics of the problem don't interest you. On the other hand, if you'd really like to understand the inner workings of the mathematics, any of the references at the end of this article will be more than sufficient.

The program loop is divided into four main parts: The first uses the current approximation to the inverse Hessian matrix (this contains what I've previously called the global topology information). The current values of the derivatives of your function with respect to each of the parameters are also used to obtain a search direction. As long as the matrix remains positive definite, the theory guarantees that we will always point downward. So, our minimum will decrease at each step if nothing goes awry.

In the second part, the step size is optimized with a linear search along the direction chosen in part 1. A reasonable trial step size is attempted, and the value of the function and its derivatives are calculated for the new location. Once again, if everything works, this trial step brackets the true minimum. A cubic interpolation between the previous position and the trial position will find our new minimum. Although this search doesn't have to be exact, we can run into problems here. The system will quit if the cubic interpolation fails because of strange geometries; if the minimum was not bracketed, a step size larger than the trial may be attempted. In any event, the result of this step is a new proposed minimum.

In the third part we decide whether or not we've finished. If the new minimum isn't lower than the old one, we stop because the rounding off is probably killing us—the new minimum is always supposed to be lower. (Incidentally, this means you cannot go out of a valley to a lower valley unless something unusual happens.) We'll also quit if the estimated distance to the minimum, as computed internally by the program, is smaller than the first stopping criterion.

We stop if the percent change in the minimum (from the previous value) is less than the second stopping criterion. No matter what happens, we stop if we've used up the number of iterations allowed by the user. If we decide to exit, the reason for stopping is returned to the main program.

Should we make it through part 3, we prepare for another iteration. Here, derivatives of the function at the new minimum are computed (so that they'll be ready for part 1 on the next go-round). The inverse Hessian matrix is updated here too, using either the Davidon-Fletcher-Powell or Broyden-Fletcher-Goldfarb-Shanno updating method. Both of these methods guarantee that the inverse Hessian will remain positive definite, so the new minimum will indeed be lower than the old one. If the steepest descent is being used, the update is skipped because the identity matrix is always used in this case. The update completed, we return to part 1 above for another spin through the loop.

As you've probably noticed, derivatives are computed twice per iteration in this scheme, a penalty of all methods that include a linear search. When minimizing using experimental data sets with many points, the computation of the derivatives is by far the most time-consuming process. Each time we evaluate the derivative vector, we need to make  $2n$  function calls, where  $n$  is the number of parameters in the function. The number of function calls per iteration is approximated as  $4n + 2$ . Anything you can do in your function to speed things up will have a great effect on total computation time. The other computations take much less time.



A final word on the derivatives—there are  $2n$  function evaluations per derivative because the derivatives are computed by a simple symmetric finite difference. The function is computed once after adding an epsilon to the value of the parameter in question. It's computed a second time after subtracting an epsilon. Then we take the difference, dividing by twice epsilon and holding all other parameter values constant.

Note that if the epsilon is too small, the derivative will be imprecise (because we may be subtracting two numbers that are almost equal and then magnifying the difference by dividing by a small number). On the other hand, if the epsilon is too big the approximation of the derivative—the secant instead of the tangent, as it were—will be too gross. This problem has no easy solution. The default is set to something reasonable, and the derivative calculation can be examined by setting "debug" to 3 (more on this in a moment). You can then set derivative step sizes individually for each parameter on input. After that you have to fend for yourself.

### The Program

The program I have just described solves only small- to medium-size problems; it's dimensioned to handle up to ten parameters, although you can adjust this number. To complete the program, you need to add a function representing your model, compile that function, and link it with the other modules. The load module then does the minimization, subject to various input commands you give it. Actually the design of the system is predicated on building a library of models so that various optimizations can be performed against sets of data—more on building this library in a moment.

My version of the system was built on an Osborne computer (running CP/M 2.2) using Software Toolworks's C/80 compiler (Version 3.0) with floating-point support. Digital Research's relocating assembler, library manager, and linker were also used. All these products were up to the task, although a special tip of the hat goes to Walt Bilofsky's folks at Software Toolworks for an exceptional product.

Most of the C code should port easily to other machines. The file `global.h` that is included in all source files contains conditional compilation directives to ease the porting task. For example, the Software Toolworks compiler doesn't support the type `double`, so I've included a `#define` for the C/80 compiler to change all `doubles` to `floats`.

If you're using the C/80 compiler, leave the `#define C80` statement in `global.h`. Otherwise, remove it to get the standard `#includes` for `stdio.h` and `math.h`. I used some of Software Toolworks's library functions: `atoi`, `atof`, `fabs`, `strcmp`, `strcpy`, `strlen`, `isspace`, `fopen`, and `fclose` are Unix-like and should pose no problems. I've assumed that `isspace()` is a subroutine rather than a macro, however. If `isspace()` is defined by

```
#define isspace(c) ((c) == ' ' || (c) == '\t' || (c) == '\n')
```

the invocation

```
isspace( *p++ )
```

is expanded to

```
(*p++ == ' ' || *p++ == '\t' || *p++ == '\n')
```

where `p` is incremented three times if it's not a space, tab, or new line.

Two other portability problems are resolved by the `#define C80` statement—the use of `getline` instead of `fgets` and the need to use `%lf` rather than `%f` in `scanf` calls when using `doubles` instead of `floats`.

`Lint` is unhappy with one part of VMM.C. The problem has to do with passing around pointers to functions. VMM.C needs to read a string containing a function name, look up that function in a table, and then pass the address of the function back to the calling program. So, we have to declare a function that returns a pointer to a second function that, in turn, returns a `double`. The correct declaration syntax is:

```
double ( *obj(a,b) ) ( )
double a, b;
{
    ...
}
```

The argument list has to be in the innermost set of parentheses. Unfortunately, the normally stalwart C/80 doesn't accept this declaration. There is a convenient, though very nonportable, way to work around it, though. In fact, some compilers won't accept the code as given in the listings. I assumed that an int and pointer are the same size (a valid assumption in an 8080) and then wrote the code accordingly. Listing Nine (next month) shows the essentials of the VMM code as it stands. Listing Ten (next month) is a short sample program that shows the changes you have to make for the program to be correct.

It's obviously to your advantage to use an 8087 if you have it; the calculations in the program are floating-point intensive.

As I mentioned earlier, you'll have to provide a model of your function as a C subroutine. I've provided several templates that you can look at to see what this model should look like. You must respect the number and type of all arguments to the function call; even if you don't use all of them, they all must be included for consistency. The variable `user` (in `main()`) lets you communicate with your function from the outside; when the minimizer calls your function, it calls it with `user` set to 0.

You must update the function library routine (`funlib()`) in VMM.C, Listing Two, page 76) every time you add a function to the system. You can find detailed instructions for updating `funlib()` in the comments in the code. Briefly, a few tables need to be changed. The system chooses a function interactively at run time, and the tables serve to automate the function selection process. These tables tell the program what the function is called when input is being interpreted, what name it has in the system, how



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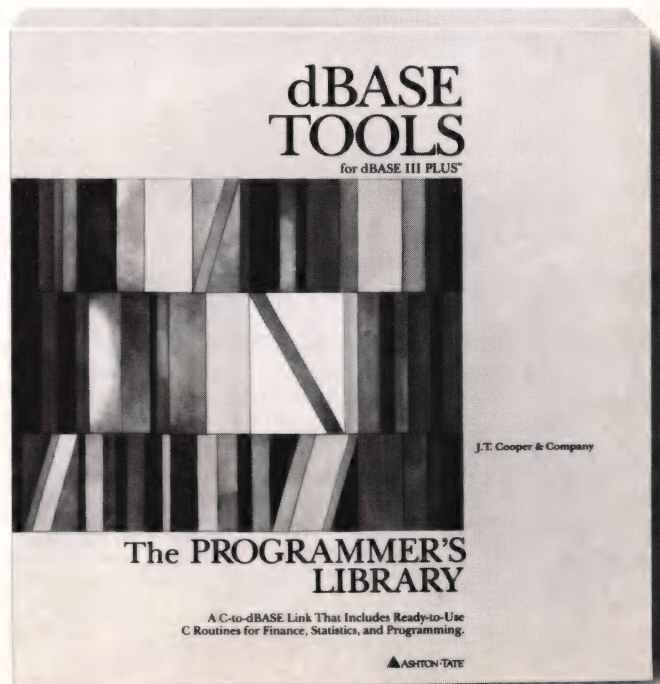
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many parameters it has, how many constants it has, and what names you have chosen for the parameters.

Adding a function is easy. By grouping the main program, the function library routine, and all the user functions in VMM.C, all the things that you're likely to change are isolated in one module, so VMM.C is the only module that ever needs to be recompiled. To rebuild the system, edit VMM.C, recompile it alone, and then link it to the remainder of the system. You may want to put the other modules into a library to ease the linking process.

Before modifying the system, it's best to get it working and play with it for a while. Compile and link all the modules provided, and then run the program using the sample data file I've provided (a1.dat, Listing Eight, next month). Unix-style redirection can be used to both enter the data and put the results into a file:

```
A>VMM <A1.DAT >A1.RES
```

You can interactively input the commands found in a1.dat too and see the results directly on your screen.

### The Program's Output

Some of the program's behavior deserves comment. There are several levels of debug printout, so you can have the program glide through to the result quickly and silently or you can see it work in three levels of detail. Silent operation is important if the minimizer is embedded into another application. Sometimes, however, it is important to see what the program is doing. Debug level 1 prints out some summary results at each iteration. Level 2 displays details of how the program is making its internal computations and decisions. Level 3 goes one step further and provides details of the derivative calculations.

You can set the debug level for each data case as part of the data input process.

bfgs	select BFGS method
constants	set constants in function
debug	set debug level
derivsteps	set step size for derivatives
dfp	select DFP method
end	exit program
epsilons	set stopping criteria
exmin	set expected minimum
funname	select function (req'd first)
iterlim	set maximum iteration
itermin	set minimum iteration
limitflags	set limits on parameters
lowerlimits	set lower limits
newdata	read a data file
next	do this data set, then read next
pstart	set starting values for parameters
reset	set reset value on update matrix
sd	select steepest descent method
upperlimits	set upper limits

**Table 1:** VMM keywords

### Command Input

Another area of interest is the command input process. I've tried to make the program easy to use without robbing it of its flexibility for advanced users. Most of the important parameters can be adjusted on input, although a case can be run with as few as three commands: one to name the function to use, one to give the starting values for the parameters, and one to invoke the calculation for that case. Multiple cases can be stacked in one run. Each of these cases is referred to below as a data set.

As you can see from the code (and from the sample data in Listing Eight), input is formatted as a keyword followed by either zero or more numeric values or strings. If the first word on the line is not recognized as a keyword, the entire line is taken as a comment. This is convenient for embedding comments in the output listing as all input commands are echoed, but might cause trouble if you're not paying attention when entering data. Recognized keywords are shown in Table 1, below.

The first command in any data set must be *funname*. This command should be followed by the name of the function to be looked up in the library. (The table that you set up in *funlib*( ) tells the program how many parameters and constants this function requires.)

The only other mandatory command is *pstart*, which takes as arguments *n* floating-point numbers corresponding to the starting values for the *n* parameters expected by the function named in *funname*.

The minimization algorithm can be selected with one of the *sd*, *dfp*, or *bfgs* commands. These correspond to steepest descent, Davidon-Fletcher-Powell, or Broyden-Fletcher-Goldfarb-Shanno methods. The *dfp* command is used by default.

The minimum and maximum number of iterations are specified with the keywords *itermin* and *iterlim*, each followed by a fixed-point number. If these commands aren't used, defaults of *n* and *2n* (where *n* is the number of parameters) are assumed.

The *reset* command tells the program to reset its update matrix periodically after a specified number of iterations. If you don't issue a *reset* command, a default of *3n/2* is used.

Stopping criteria can also be specified. By default, if the estimated distance to the minimum becomes less than *1.0e-06* or the fractional change in the minimum becomes less than *1.0e-03*, the program will stop (provided that the minimum number of iterations has been executed). You can alter these limits with the keyword *epsilons* followed by the limit on the estimated distance to the minimum and the limit on the fractional change (in that order). Both numbers must be entered, even if you want to change only one of them.

One or more parameters can be constrained to a specified range using the *limitflags*, *lowerlimits*, and *upperlimits* keywords. The three must always be used together. *Limitflags* is followed by *n* integers set to either 0 or 1, turning limit flags off or on. If the flag is set to off (the default if a command is not used), then there are no constraints on that parameter. The keywords *lowerlimits* and *upperlimits* must be followed by *n* floating-point values for the lower and upper limits on each parameter; the values for those parameters with flags set to 0 are



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3/86 DDJ



ignored. An example of the process is given at the top of Listing Eight. Constraints on parameters are very useful when, for example, you know that a certain parameter must be positive (it might be a physical dimension). In this case you can set its lower limit to 0.0 and its upper limit to some large number. You can also fix a parameter by setting its limit flag to 1 and setting its lower and upper limit to its starting value (this particular use of limits is rare but may prove useful). Constraining parameters slows down the system significantly as there are several places where a trigonometric transformation must be employed to convert from a bounded interval to an infinite one and back again.

The *derivsteps* keyword lets you set the size of the interval used for computing the derivative. The default interval is 1 percent on either side of the current value.

The keyword *exmin* adjusts the expected value of the minimum (0.0 is the default).

To allow you to find best sets of parameters for whole families of functions, your function may use several constants, set using the keyword *constants* followed by *m* floating-point values for the *m* constants that your function requires. Constant values are remembered from data

set to data set as a convenience. Nevertheless, if you change functions you must include a new *constants* statement to avoid using the old constants.

*Debug* sets the debug level; follow it by 0, 1, 2, or 3. Note that the debug diagnostics start being printed as soon as this command is issued, so putting it in at the start of a data set gives you debug diagnostics as part of the input echo. Debug level 0 (no diagnostics are printed) is the default.

Use the *newdata* command to read a file with experimental data. Follow the command with the full file name for the data (e.g., *b:exp.dat*). The data file is assumed to have a very specific format: The first element is the number of lines to read from the data file (extra lines are ignored). The rest of the file is data (in floating-point format). The *x* value must be entered first, then the *y* value. The data is put into an array of structures called *exp* (defined near the top of Listing Two). If you need something different (such as three numbers instead of two), you'll have to change the definition of the *DATA* structure (in *global.h*), as well as the associated input routines, and then recompile. Note that the maximum number of data points is defined as *DMAX* in the main program and will probably need to be enlarged. If you want to echo the data as it's read, turn on the debug before requesting *newdata*. The program aborts if it can't open the data file.

One caveat with *newdata*: Data read into the array persists from one data set to the next (in the same way as do constants). It didn't make sense to have to reread the data from disk for each new case if the same data was being used. Anyway, if you want to change data files from one case to another, you must issue a call to *newdata* with a different file name. Incidentally, I used the keyword *newdata* instead of something such as *data file* to emphasize that you are in fact reading in new data.

The *next* command starts up the algorithm (moves you from a Data Input to a Run mode) for the current data set. With the exceptions of data entered with *newdata* and constants read in with *constants*, each set starts with a clean slate—there's no carry-over from the previous data set. If debug was set to 1 on the previous data set, and you still want it to be 1, you must request it again.

The keyword *end* causes the program to terminate.

If an error is detected in a data set, the set is skipped. If the reason for the data error isn't obvious, the case should be run a second time with debug set to 1 at the very start of the case. You can always reset it to 0 just before issuing a *next* command, thereby getting additional debug print-out just for the input stage. Sometimes the error is caused by a mistyped keyword, which causes the whole line to be treated as a comment. If debug is set to 0, there's no indication that this has occurred. The program always tells you how many commands and how many comment lines it's read, however, so you have a quick way of checking for this problem even if debug is off.

### Benchmarks

I ran two benchmarks to show the relative performance of the various algorithms mentioned earlier (see Tables 2, left, and 3, page 32). The Rosenbrock function:

$$F = K * (x_2 - x_1^2)^2 + (1 - x_1)^2$$

8 bits (Osborne I)  
single precision  
Z-80, CP/M 2.2  
5¼-inch floppy

Scale	Method	Result	Minimum	Iterations
Starting values: (-1.2, 1.0, . . . -1.2, 1.0)				
100	sd	-.67140, .45982	14.	4
	dfp	-.860, .749	17.	7
	bfgs	-.84, .71	17.	7
10	sd	.889, .788	6.1 E-2	20
	dfp	.99, .99	7.4 E-5	20
	bfgs	.98, .97	1.5 E-3	20
1	sd	.96809, .92871	5.5 E-3	20
	dfp	.99982, .99964	1.6 E-7	10
	bfgs	.99996, .99994	8.3 E-9	10
Starting values: (1.2, 0.8, . . . 1.2, 0.8)				
100	sd	.95171, .90560	1.2 E-2	10
	dfp	.9825, .9651	1.6 E-3	9
	bfgs	1.0036, 1.0072	6.8 E-5	8
10	sd	.96279, .92363	7.5 E-3	20
	dfp	.9986, .9971	1.0 E-5	7
	bfgs	.99842, .99678	1.3 E-5	7
1	sd	.99944, .99869	1.7 E-6	10
	dfp	.99986, .99971	1.0 E-7	6
	bfgs	.99983, .99963	1.6 E-7	6
Time (total)				670 seconds
Time per run				37.2 seconds
Time per iteration				3.2 seconds

**Table 2:** 8-bit benchmark



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was used. F is 0 when

$$x_2 = x_1^2 \text{ and } x_1 = 1$$

So, at  $x_1 = 1$ ,  $x_2 = 1$ , we have a minimum for all  $K > 0$ .

The constant K allows us to "scale" the two terms; for  $K = 1$ , the two terms have about the same contribution to F in the neighborhood of the minimum. As K becomes large, the problem becomes progressively more difficult: The first term, which "drives"  $x_2$  to be  $x_1^2$ , will swamp the second term, which drives  $x_1$  to 1. For  $K = 100$ , we would expect to see  $x_2$  approach  $x_1^2$  but not see  $x_1$  go to 1. I have included tests with  $K = 1$ , 10, and 100 on an extended Rosenbrock function using ten instead of two variables; that is, the function is made up of ten terms consisting of five pairs of variables related in the same way. The tests have been done using a poor starting point  $(-1.2, 1.0)$  and a fairly good starting point  $(1.2, 0.8)$  so you can evaluate the importance of a good starting value.

All tests were performed using the same maximum number of iterations (20). The inverse Hessian approximation was reset every five iterations in the *dfp* and *bfgs* methods. The factor K is called scale in the tables.

16 bits (Intel 86/30 System)

double precision

8086/8087, Xenix

25 Meg hard disk

Scale	Method	Result		Minimum	Iterations
Starting values: (−1.2, 1.0, . . . −1.2, 1.0)					
100	sd	−.67131,	.45970	14.	4
	dfp	−.64703,	.42826	14.	7
	bfgs	−.63495,	.41267	13.	7
10	sd	.89008,	.78805	6.1 E−2	20
	dfp	.9983,	.996	1.3 E−5	20
	bfgs	.999,	.998	8.1 E−6	20
1	sd	.96809,	.92871	5.5 E−3	20
	dfp	.99980,	.99961	2.0 E−7	10
	bfgs	.99980,	.99960	2.0 E−7	10
Starting values: (1.2, 0.8, . . . 1.2, 0.8)					
100	sd	.95171,	.90559	1.2 E−2	10
	dfp	.981,	.9624	1.8 E−3	10
	bfgs	1.0031,	1.0062	4.8 E−5	10
10	sd	.96279,	.92363	7.5 E−3	20
	dfp	.99846,	.99668	1.5 E−5	5
	bfgs	.99837,	.99650	1.6 E−5	5
1	sd	.99943,	.99872	1.7 E−6	10
	dfp	.99986,	.99970	9.7 E−8	5
	bfgs	.99982,	.99962	1.6 E−7	5
Time (total)				81 seconds	
Time per run				4.5 seconds	
Time per iteration				0.4 seconds	

Table 3: 16-bit benchmark

The correct result is  $(1.0, 1.0, \dots, 1.0, 1.0)$ , which would be indicated below as 1.0, 1.0. The number of digits in the result shows how much the answer varies from pair to pair among the five pairs of results. The minimum should be 0.0.

### The Listings

Several listings are provided with this article. Global.h (Listing One, page 74) is the global *include* file mentioned earlier. It contains conditional compilation switches for the C/80 compiler versus other C compilers.

VMM.C (Listing Two) is the main program, the function library module, and all the functions in the library. For the time being, there are three functions: *cohen*( ) is the test problem in Cohen's book (see the reference in code), *sine*( ) finds coefficients for a polynomial approximation by fitting sine data, and *rosen*( ) is used as a benchmark. You'll have to compile, assemble, and then link this file to add a function to the library. All the other files may be kept in object format and just linked to VMM.OBJ (or .O, .REL, or whatever) to generate a new load module.

MINIM.C (Listing Three, page 82) contains the main minimizer routine.

AUXLC (Listing Four, next month) contains the line search procedure and the decision logic for stopping the minimization.

UPC (Listing Five, next month) holds the routines required for updating the "topology matrix" according to the DFP or BFGS methods.

UTIL.C (Listing Six, next month) contains a variety of utility routines. Among these are routines for transforming from external to internal coordinates when dealing with constrained variables, routines for calculating derivatives, routines for initializing everything at the beginning of a data set and for setting proper defaults, vector and matrix output routines, and routines for various matrix and vector manipulations.

READ.C (Listing Seven, next month) is the input interpreter. There are a few conditional compilation directives in this module so that *scanf* will handle *floats* and *doubles* correctly.

A1.dat (Listing Eight) is a sample input for a test run, including the Rosenbrock benchmark mentioned above. A1.dat reads in sine.dat (Table 4, below), which contains the experimental data for the function *sine*( ).

### Availability

This program is put in the public domain for personal,

20			
.050000	.078459	.550000	.760406
.100000	.156434	.600000	.809017
.150000	.233445	.650000	.852640
.200000	.309017	.700000	.891006
.250000	.382683	.750000	.923879
.300000	.453990	.800000	.951056
.350000	.522499	.850000	.972370
.400000	.587785	.900000	.987688
.450000	.649448	.950000	.996917
.500000	.707107	1.000000	1.000000

Table 4: sine.dat



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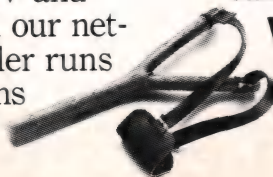
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(Continued from page 32)

nonprofit use only. Permission is granted to reproduce it, but I would appreciate your commenting any changes you make. As the publicly available source code is obviously beyond my control, I can assume no liability for subsequent versions.

This source code is available on several CP/M remote BBSSs, in particular on the Mountain View RCPM (415) 965-4097 and the First Osborne Group (FOG) RBBS #1 (415) 755-2030. Both of these systems provide free downloads to members satisfying nominal entry requirements.

I plan to keep a list of registered users in order to support continuing development and evolution of this system. Registered users participate in a common pool of bugs and bug fixes as well as potential future updates. To become a registered user, send a check for \$25 to: Billybob Software, P.O. Box 363, Belmont, CA 94002-0363.

A registered user can obtain the source code on a 5 1/4-inch disk by sending a preformatted disk and sufficient return postage to the above address. Be sure to indicate what format your disk is expecting. The most recent version will be returned. I can handle many CP/M formats as well as PC DOS and MS DOS formats; if you require an unusual format, send a postcard and I'll let you know if I can accommodate you.

## Bibliography

There are lots of good books in this field, and the list given here could easily be three times longer. I've tried to include those books that specifically address the minimization problem.

Acton, F. S. *Numerical Methods That Work*. New York: Harper & Row, 1970. One of the best overall treatments of minimization, there are both wisdom and technique in this book. It's a good place to start if you're new to numerical analysis.

Cohen, A. M. *Numerical Analysis*. New York: Halstead Press, Wiley, 1973. This book is a paperback, inexpensive but solid. Cohen's notation is used throughout the program described in this article. He describes the Davidson-Fletcher-Powell method only.

Dennis, J. E., and Schnabel, R. B. *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*. Englewood Cliffs, N.J.: Prentice-Hall, 1983. A definitive work in the field but it's very theoretical.

DDJ

(Listings begin on page 74)

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```
RD  READ "NAME: ",NAM,! QUIT:NAM=""
    IF NAM'?2.A1","1A.E WRITE "PLEASE ENTER AS LAST, FIRST MI",! GO RD
TEL  READ "TEL # ",TEL,! IF TEL'?3N1"-4N WRITE "NNN-NNNN PLEASE",! GO TEL
    SET ^DATA(NAM)=TEL GO RD
PRT  WRITE "      NAME",?20,"TELEPHONE #",! SET NAME=""
LP   SET NAM=$ORDER(^DATA(NAM)) QUIT:NAM="" WRITE NAM,?20,^DATA(NAM),! GO LP
```

This simple program accepts, screens and saves names and phone numbers... sorts and prints them. These six lines of code are an example of the extremely compact, and familiar nature of COMP Computing Standard MUMPS, the Database Language. In lines 1 and 2, READ, IF, WRITE and GO should be easy to follow. The pattern match operator "?" filters for the correct input of alpha characters to make a name. In line 4, SET ^DATA creates a permanent global file, with NAM as a subscript. The data node is SET to the telephone number. In line 6, the \$ORDER command gets the next subscript in order, from the ^DATA file, thereby SETting NAM to the next name in the file.

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# Concurrency and Turbo Pascal

by Ernest E. Bergmann

## *An appropriate use of coroutines is in monitoring the keyboard and the serial port under a terminal program.*

**A**fter much trial and error, I have developed a method to use Turbo Pascal (CP/M-80) to implement several concurrent tasks. These techniques are useful for writing software that must respond to several real-time events, such as a modem program. In this article, I will explain what concurrency is, what it is useful for, and how to achieve it. Turbo Pascal provides a convenient way to become acquainted with multitasking because of the ease of writing and trying variations quickly and clearly.

### **Subroutines vs. Coroutines**

A subroutine or function call is frequently used in programming to carry out a "subtask" that a main task needs in order to continue. Economy of coding occurs when this same subtask is needed in several different places. The subtask is subservient to the main task in that its existence depends upon being called upon by the main task.

A pair of coroutines should appear to proceed in random order, namely the starting or completion of either routine is not in complete lockstep with the other routine. Doing several things at the same time is often called multitasking; it is an important feature of the languages Modula and Ada.

An example of a possible use of coroutines is the implementation of a terminal program on a personal computer. In this case, one task has the responsibility of monitoring the keyboard. Every time a key is pressed, the corresponding character is sent out of the serial port. The other task monitors the serial port

for incoming characters, and when one arrives, it is sent to the display. These two tasks are more or less independent as they do not need to share any function.

An important characteristic of the operation of such a program is that you do not assume that the arrival of characters at the serial port is closely related to tapping the keyboard. Failure of characters to arrive from either source should not interfere with the operation of the other task.

A skeleton of the program should be:

```
task1;
  begin
    repeat
      serout(keyin);
    until false{forever};
  end;
task2;
  begin
    repeat
      videout(serin);
    until false{forever};
  end;
```

Each of the tasks resembles the main procedure of a Pascal program. As is good form in structured programming, all the tough work gets put off to be written in the subrou-

tines and functions (particularly *serin* and *keyin*). Before I discuss the subroutines in detail, note that, for the tasks to run independently of each other, they need to have separate stack spaces. The stack is used to save return addresses (among other things) when subroutines and functions are called. If both tasks shared a common stack, there would be an undesirable tendency for return addresses (and possibly data) to get confused between the two tasks. Thus, each task should be assigned its own stack.

In Listing One, page 88, you can see that *task1* and *task2* indeed start by assigning their own stack spaces. Although *mystack* is declared as a variable in both *task1* and *task2*, the tasks are assigned separate memory locations by the Turbo Pascal compiler. The compiler assigns different locations for every variable of the main program and for every parameter, return value, and variable of every function and procedure.

The two functions *keyin* and *serin* are characterized by taking an unpredictably long time to complete their tasks—for example, *keyin* could take hours if the keyboard operator fell asleep (and meanwhile other things might be happening). These two functions consist of a loop where the function (tediously) asks whether a character is available. It is in these loops that most of the time is wasted; as soon as a character becomes available, the function can return its value.

The crux of accomplishing concurrency is to share the processing power between tasks. This sharing is accomplished by the calls to *defer* done by *keyin* and *serin*. *Defer* is treated as a procedure, but it succeeds in switching the processor from one task to another (hence the choice of

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name). It should be invoked wherever a procedure might not proceed quickly. *Defer* should also be invoked from time to time if rapid response to external events (such as key presses) is needed and a procedure or function is doing extensive calculations.

I found it convenient to treat the main portion of the program as *task0*; it is special in that it is given initial control when the program starts. It must initialize variables for *defer* to operate; other initializations can be done here as well, such as sending commands to hardware to configure baud rates and so on. In addition, the way the program should terminate is through the main procedure; the Pascal compiler does not empower the subroutines to terminate the program in a normal manner. To help in start-up and termination, two procedures, *initall* and *exit*, are provided.

The coding of *defer* was arrived at after some experimentation. I found, for example, that assigning an array element with the hardware stack pointer (*stackptr*) results in a different value than assigning a simple variable with *stackptr*. The reason is that the compilation generates code that pushes an address pointer for the element on the stack and so affects the value of the stack pointer at that moment.

When *defer* is called, the return address in the calling task is on the (current) stack. When *defer* switches stack pointers (thus switching to the stack of another task), it will return to the point in the new task where *defer* had been called.

A task is entered at two places: at the start and reentry (from where it had been deferred). It is necessary for *defer* to know which (re-)entry to use. This is accomplished with a test of the saved stack pointer. If the saved value is zero, then it can assume the task has never been entered and it should start at the beginning. When a task is started, it should immediately initialize the stack pointer to its own stack space.

In the interests of clarity and easy modification, the scheduling aspect of *defer* has been broken off into a separate procedure. The functioning of schedule here is almost trivial; it is apparent that for special applications with more tasks, you might

wish to try other scheduling algorithms than round robin.

The beauty of using the procedures *initall*, *defer*, *schedule*, *exit*, and the like is that they may be used as black boxes—the details of how they work can be ignored in their use. Once I had written them, I concentrated my efforts on coding each individual task.

### Reentrancy

Emboldened by my success with us-

ing Turbo Pascal to implement multiple, independent tasks, I went on to try multitasking with procedures that are shared among several tasks. My first attempts failed miserably, and I learned the hard way that procedures and functions in Turbo Pascal are not reentrant even if they may be recursive.

A requirement of Pascal is recursion, which is supported by Turbo Pascal (using the {*SA-*} option). Recursion is where procedures or func-

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## CONCURRENCY

(Continued from page 37)

tions call themselves directly or indirectly (by calling other procedures or functions that call them). An example of recursion would be the implementation of *autoCR*. *AutoCR* precedes a line feed with a carriage return:

```
procedure putc(c: char);
begin
  if c=LF then putc(CR);
```

end;

You cannot assume that all languages support recursion—for example, FORTRAN does not. To support recursion it is necessary that each invocation of a procedure has its own distinct variable space. If the space is not unique (if recursion is not supported), then in the above example the value of *c* would be changed by the second invocation of *putc* to a

CR and in all likelihood, the LF (the original invocation) would not be printed but replaced by a CR; two CRs would be produced instead of the desired CR-LF sequence.

Although Turbo Pascal supports recursion when you use the {SA-} option, it does not support reentrancy. For a procedure to be reentrant, it must be possible to defer in the middle of an invocation, switch to another task, and for that other task to reenter the same procedure without affecting the subsequent operation of the first invocation of that procedure. It was assumed in the development of Turbo Pascal, I presume, that it would not be used in a multitasking environment.

The most straightforward way around this difficulty is not to require reentrancy. Any procedure or function that might be deferred directly or indirectly and that is called by more than one task should be duplicated as many times as is necessary so that each copy is used by only one task. Listing Two, page 90, is an example of this approach.

Listing Two is a program I developed to demonstrate the use of queues to enable tasks to operate more independently of each other. In operation, it displays the characters typed at the keyboard on the screen. What is noteworthy about this program is that it is quite easy for the typist to type faster than the display rate and, thus, to "type ahead." The display continues to show more and more characters even after the typist has paused; no characters have been "lost" by the slowness of the display relative to the keyboard.

To make things more interesting, I provided the XON/XOFF protocol to make the display stop altogether on demand and to resume on demand later. If you were to type a Ctrl-S then the display would not show any activity even though you might be typing another sentence or two. When you eventually type a Ctrl-Q, the display will reactivate and show whatever was held back.

As a touch of friendliness, you can correct your typing by typing a backspace to undo the last character typed. An additional convenience is that the program provides line feeds after any carriage return you type to put you on the next line without

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your having to remember to type the line feed as well. Should you type a line feed, it will be discarded.

Listing Two consists of three tasks. The first task (*keyboard*) gathers whatever is typed and quickly stores it away so that it can be digested at leisure without missing any keystrokes. The method of storage is known as a queue, reminiscent of people standing in a line in which the first person in line is the first to get service. Another expression for the same technique is FIFO (first in, first out). No one seems to use the acronym LILO (last in, last out), although it probably would be understood equally well. In any case, the first task places all characters received into the first queue by calling the procedure *enqueue1*.

The second task is called the *filter*. Its function is to take each character that it obtains from the queue of characters received by *task1* and either pass them along or carry out particular actions. If a carriage return is encountered, you want a line feed to follow it. If a line feed is typed, it is to be dropped. Ctrl-S and Ctrl-Q characters are not passed along but are used to stop and start the output, respectively. A Ctrl-C causes the program to quit. Most characters are passed along.

The output of the *filter* does not go directly to the output device but is placed in a second queue awaiting a chance to go to the display whenever the display is ready to take this output. Thus the *filter* produces output by calling the function *enqueue2*.

The third task, *printer*, takes characters from the second queue by calling *dequeue2*. *Dequeue2* either returns with a character right away or may take its time (deferring to other tasks). Delays in returning a character mean that there are no characters (and you need to wait for the *filter* to supply some more) or that the queue is in a "noflow" state. Because the video display is normally very fast, I chose, for purposes of illustration, to slow the printer task artificially by requiring it to count up to PRATE before sending each character.

Notice that the functions *occupancy(p)* and *vacancy(p)* are each used by more than one task. *Task1* uses *vacancy* (through *enqueue1*). *Task2* uses *occupancy* (through *dequeue1*) and

*vacancy* (through *enqueue2*). *Task3* uses *occupancy* (through *dequeue2*). The functions *occupancy* and *vacancy* can be "shared" between several tasks because they never defer.

On the other hand, I have learned the hard way not to try to share *enqueue(p)* and *dequeue(p)* because these functions would defer, and they need to be reentrant. Thus I have separate but equal procedures: *enqueue1* and *enqueue2*. Also, I have the separate functions *dequeue1* and *dequeue2*.

## Conclusion

It is relatively easy to create a multi-tasking program with Turbo Pascal in CP/M-80 using the method I have shown here. You have to be careful, though, that functions or procedures that need to be reentrant are replaced by several copies to avoid that need.

DDJ

(Listing begins on page 88.)

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# The Problems of Parallelism

by Michael Swaine

***Parallel processing involves both a rethinking of system architecture and a fundamental recasting of algorithms. It's a Knuth 50 task.***

**L**ife has a grammar with four terminal symbols. G, T, A, and C (guanine et al) are four chemical bases that combine to form the two-stranded, helical molecules of DNA, the grammar behind all life on Earth. In pairs, the bases form sequences up to hundreds of thousands of base pairs long that define the genetic makeup of an organism. Several thousand such functional sequences of base pairs have been identified, but they represent only a small fraction of the possible sequences. Having learned that structural similarity is the first clue to functional similarity, molecular biologists such as J. Douglas Welsh at Princeton University begin the process of identifying the function of each new sequence by comparing, base pair by base pair, the new sequence with existing sequences. Unraveling the thread of life is a problem in pattern matching.

Many good algorithms for pattern matching are known, but good algorithms are not always good enough. Welsh found that the problem was using more computer time than he could afford, and he worried that the pruning heuristics he employed to focus only on "relevant" sequences would cause him to overlook important functional sequences. He wanted to search both exhaustively and efficiently. Existing algorithms and architectures seemed to prevent him from doing so.

Those who read the discussion of the Fgrep algorithm in *DDJ* (September 1985) will recall how algorithms that do pattern matching in parallel can sometimes outpace their sequential counterparts. Princeton graduate student Daniel Lopresti, enlisted to

solve Welsh's problem, followed a similar insight and found a parallel algorithm that he estimates can produce a thousandfold increase in processing speed over the algorithm Welsh had been using. Lopresti has implemented his algorithm in a multiprocessor chip that represents an advance in the technology for molecular biology and could also find applications in many other disciplines in which string comparisons are important.

Lopresti's example shows that replacing traditional sequential algorithms with parallel algorithms can produce significant increases in throughput and efficiency. In fact, problems that have been shown to be NP-complete and to require exponential time to solve by sequential methods can often be solved in polynomial time, and sometimes in linear time, using parallel techniques. The development of appropriate parallel algorithms for fundamental problems such as searching, sorting, pattern matching, matrix operations, fast Fourier transforms, and so on is by no means a simple matter, however. Like Lopresti, the designer of a successful parallel solution to a programming problem today is likely to

be programmer and microprocessor designer in one body because implementing a parallel solution tends to involve the entire computational model, and the parallel algorithm can rarely be viably grafted onto an existing sequential Von Neumann architecture.

## **Concurrency**

There are, of course, many examples of concurrent processing in otherwise sequential architectures. Concurrency at the level of the operating system in the case of Concurrent DOS or at the "operating environment" in the cases of TopView and DESQview, for example, allows entire applications to run in what is, at that level, parallel fashion. At a deeper level, the machine is executing instructions in strictly sequential fashion. Taking it a step higher, one can implement concurrent processes within an application program; IBM claims that TopView will support concurrency within the programs that it is running concurrently. Another article in this issue examines the techniques for implementing concurrent processes. (See "Concurrency and Turbo Pascal" by Ernest Bergmann.)

There are also examples of deeper concurrency that still don't force any serious rethinking of fundamental algorithms or of the architecture of the machine. Print spooling and the use of dedicated math coprocessors both split off easily segregated operations and hand them off, freeing the CPU for other operations. A more complex separation of functions was presented by James Vaughan and Robert Smith of Tantivy Associates of Palo Alto, California, at the Wescon show last November. Their machine implements a structured sequencer that operates in parallel with arithmetic operations. The sequencer just

Michael Swaine, 2464 Embarcadero Way, Palo Alto, CA 94303



traverses a tree; it supplies the calling and branching operations of traditional sequential programming. The computational component is a coprocessor that performs all the traditional arithmetic operations, passing single-bit messages to the sequencer and picking up its instructions and data from it. But the resultant concurrency between sequencer and processor is, as Vaughan himself points out, similar to the kind of concurrency that exists between a main processor and a math coprocessor in a personal computer.

### Parallel Processing

True parallel processing involves both a rethinking of system architecture and a fundamental recasting of algorithms. It exists. There are parallel-processing computers in existence today, and more are on the way. Full use of those computers—exploitation of parallel processing at the level at which we have exploited sequential processing today—represents a large step forward, but it's not here yet. It's a level 50 problem in the notation of Knuth's *Fundamental Algorithms*. General-purpose parallelism in machine architecture and algorithm design may well require cooperation on the level of the efforts that produced the sequential machines of the 1940s. That cooperation is not always present.

A year ago, Peter C. Patton was growing frustrated directing efforts at the Microelectronics and Computer Technologies Corp. (MCC) in Austin, Texas, to solve the problem of decomposing tasks into components appropriate for parallel execution. After resigning his post with MCC, he expressed his frustration with the organization's lack of focus in *The Wall Street Journal*: "Most people think parallel processing is the future, but nobody can agree on how to get there," he said.

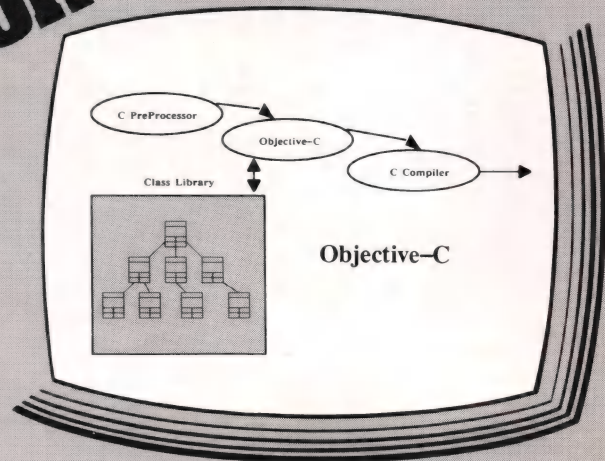
One organization trying to provide some focus is the Parallel Processing Research Council, a group that grew out of a 1983 NSF workshop on parallel-computing research. According to *IEEE Computer* (December 1985), the group plans to promote collaborative efforts in parallel-processing research among government, industry, and university researchers by producing a newsletter, distributing in-

formation about nonproprietary research and projects in parallel hardware and software, and starting two research facilities. A report issued by the council attributes any lack of progress in the area to lack of facilities and significant collaborative effort, deficiencies the group hopes to remedy.

One of the differences among ap-

proaches to parallelism is the architecture vs. algorithm distinction. It stems from the necessity of finding a good match between algorithm and architecture and the question of just how to achieve the match. Does one start with the architecture and tailor the algorithms to it or develop efficient parallel algorithms and create architectures to support them?

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## PARALLELISM

(Continued from page 41)

Perhaps the problems have to be solved in parallel.

### Architecture-Driven Design

According to Sudhakar Yalamanchili and J. K. Aggarwal of the University of Texas at Austin, writing in *IEEE Computer* (December 1985), the approach of tailoring the algorithm to the architecture can achieve high

performance at the expense of generality. They refer to this approach as architecture-driven algorithm design. In particular, architectures employing different interconnection topologies among processor, memory, and I/O resources will force recasting of parallel algorithms.

Two broad architectural approaches to parallelism are the multiple-instruction stream/multiple-data stream (MIMD) and the single-instruction stream/ multiple-

data stream (SIMD) architectures. Machines embodying each of these architectures will be appearing on desktops within a year. Ncube Corp. of Beaverton, Oregon, will be selling a four-processor card for the IBM PC/AT this year that is mostly intended for use by developers of software for the larger parallel systems the company is planning. Ncube's card employs MIMD architecture.

Apparently an architecture-driven design can at least peak out at good performance figures, even if it is not the optimal parallel solution for all problems. IIT expects to release a SIMD board for desktop computers next year. If estimates by Steven Morton, IIT's designer, are correct, machines with the SIMD board will reach performance levels up to two-thirds of a Cray-1 and cost around \$10,000.

IIT and Ncube are both developing general-purpose machines. On the other hand, there are examples, such as Princeton University's Navier-Stokes machine, of architectures developed to support particular parallel algorithms.

The Navier-Stokes equations for fluid flow are used to solve problems in fluid dynamics. The equations are good candidates for parallel processing, and Daniel Nosenchuck and Michael Littman are building a 128-node computer dedicated to solving Navier-Stokes equations. They developed the parallel algorithm and designed the machine to implement it: They expect to crank through equations at 50 gigaFLOPs, a performance level achieved at some expense in generality.

The algorithm-driven approach, in contrast to the architecture-driven approach, is suggested by Lopresti's DNA machine and by machines running Prolog programs. Prolog suggests some common methods of parallelism, chiefly AND-parallelism and OR-parallelism. The DNA machine's algorithm is specific, while the approaches to parallelism implicit in Prolog are quite general. Many problems, cast as Prolog programs, suggest a natural parallel formulation—natural for Prolog, at least. But despite such general schemes for parallelizing algorithms, the development of efficient parallel algorithms for common problems is still in its early stages.

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As in the 1940s with the development of the sequential computer and its associated algorithms, algorithms and architecture for parallel processing may have to be developed hand in hand, requiring close communication among researchers.

The Computer Measurement Research Facility of the National Bureau of Standards is collecting parallel benchmark programs. The plan is to develop a public repository of information about parallel-computer performance; the Bureau wants programs, written in high-level languages, that measure some aspect of parallel-processing performance. Direct inquiries to:

Computer Measurement Research  
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# Speeding MS DOS Execution

by Gregg Weissman

***When writing your own BIOS disk handlers using interrupt 13h, set the head settle time to 0 for all read operations.***

I was intrigued to read in Dr. Dobb's Clinic (*DDJ*, September 1985) that he thought "the DOS BIOS doesn't use the ROM BIOS for its disk input, and DOS's BIOS does it better." Because I know that this is not so (DOS does use the ROM BIOS), I thought I would experiment and discover more of the story and the answer to the riddles presented in the column.

DOS definitely uses the ROM BIOS to handle disk I/O. This can be verified by examination of the DOS BIOS code as it resides in memory or by loading the DOS BIOS file (IBMBIO.COM for PC DOS or IO.SYS for MS DOS) into DEBUG and unassembling it. Look for the INT 13 instructions: There is the disk I/O handling. You will not see any of the lowest level DMA and disk-controller handling procedures that you find in the ROM BIOS. It would be against IBM's and Microsoft's software design principles to include such low level machine dependencies in the DOS BIOS.

I used E-X-E Software's DOS200LS System Utilities package to perform timing tests to verify the benchmarks published in the column. This package contains a program to trap DOS functions and time them and another program to produce listings of the results. Five listings are included with this article, showing the results I obtained in performing some of the tests mentioned in the column.

I was able to verify most of the test results, obtaining very similar times even though the tests were performed on an IBM PC/AT and not an XT. Because the limiting factor in I/O would be the disk's physical charac-

teristics and not CPU speed, the timings would be expected to be similar.

The DOS COPY command in my test (Listing Four, page 101) ran in 9.7 seconds, compared to 9.8 seconds in Cortesi's: close enough to consider the results identical. My interpreted BASICA test (Listing Five, page 101) ran in 44.2 seconds of DOS time and 66 seconds total. Cortesi includes no figure for the time spent by DOS on the disk functions only.

In the tests that called DOS from assembly language, Cortesi claims that "block sizes beyond 9K, one cylinder, don't give further improvement." This is not what I found: In my tests (Listings Six, Seven, and Eight, pages 102-104), a block size of 9K, or 2400h, gave a result of 9.7 seconds, while block sizes of C000h through FE00h (49,152 to 65,024 bytes) gave substantially lower times, leveling off at C000h at 7.09 to 7.14 seconds (plus or minus one clock tick).

It could be that the block size at which performance levels off is a function of the disk hardware because I obtained the same results with both PC DOS Versions 2.1 and 3.1 and could verify that the BIOS calling sequences were essentially the same. There is no other way to account for Cortesi's finding that performance

did not improve past the 9K block size.

## ***The Answer to a Puzzle***

The reason Cortesi states that the DOS BIOS does not use the ROM BIOS for disk I/O, however, is based on the findings of an (unlisted) assembler program that reads the disk directly through the BIOS interrupt 13h. Because this program was slower than the fastest DOS time, he assumed that DOS does not use ROM. I knew there had to be another answer.

I tried my own assembler routine to read the requisite number of sectors directly, also using the ROM interrupt 13h. This appears in Listing One, page 94. There are only a handful of logical ways to do this, so I suspect my program is very similar to Cortesi's. My program also ran slower than DOS, timing out at 11.42 seconds. Because I knew DOS had to be using BIOS, I coded a short resident module to trap the BIOS interrupt 13h so I could see what DOS was doing as it happened.

What I found is that DOS modifies the head settle time parameter in the table of disk variables that BIOS uses to control the NEC disk controller. The head settling delay is a simple do-nothing loop in the ROM BIOS, giving the read/write head and arm time to settle into position after a seek operation is performed, before the controller attempts to read or write any data. Each time the disk has to move from one cylinder to another, this head settle delay will be taken.

The absolute memory location 0000:0078h contains a pointer to a table of values that users can modify in order to accommodate different disk characteristics. One of the parameters is the head settle delay.

The default head settle time on the

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AT is 15 milliseconds when the system is initialized by BIOS, and PC DOS 3.1 resets this to 1 millisecond. On the XT, it defaults to 25 milliseconds; PC DOS 2.1 knocks this down to 15 milliseconds. These head settle times are required when writing disk data, but not when reading, as I discovered.

When DOS reads from the disk, it sets the head settle time in the disk parameter block to 0. When the operation is complete, DOS restores the original value. Therefore, when Cortesi (and I) ran our assembler BIOS tests, the head settle time was set to the original default—in my case 1 millisecond, and in his, possibly up to 15 milliseconds.

### Two New Puzzles

If I changed the settle time parameter to 0, as does DOS, my assembler timing went from 11.42 seconds down to 7.9—but this presented two puzzling problems.

The first problem was easy: The new lower times were still greater than the DOS timings—the DOS tests consistently showed times of 7.09 to 7.14 seconds, and those times included all the operating system overhead. With a little thought I realized that the motor start-up time must be considered. The motor starts when DOS executes an *OPEN* function, which I was not counting in my comparisons.

When I started the disk motor before beginning the timing, the time required for the BIOS to read 16 cylinders went down to 6.8 seconds, the time Cortesi reports for the *DOSINT 25* function as the fastest possible (which is true). If you refer to the DOS timing figures, the *OPEN* calls all took about 2 seconds (plus or minus 1 clock tick), so everything fits neatly together.

Pay close attention to Cortesi's phrase "DOS sequential input can reach and sustain an input rate of one track per disk rotation"—naturally the best performance possible. I'll explain how and why this is so and show you how to achieve this yourself.

The attentive reader may already have thought of the second, less trivial problem. The head settle parameter is supposed to indicate the number of milliseconds of delay. Eliminating the delay on the AT by setting the count to 0 instead of 1 should save 1 millisecond per seek-

to-track. The test reads 16 different tracks, so there should be an improvement of 16 milliseconds, not more than 3 seconds.

Further tests indicated that increasing the settling time past 1 millisecond resulted in no further deterioration of performance until the count passed 90, at which time I lost another 3-plus seconds, and so on.

The solution appears easy now, but it took some work to arrive at it.

I pored over the AT BIOS listing to find out if the head settle parameter is used in some other way in addition to the seek operation. The answer is no: There is no other use of this variable other than counting the number of 1-millisecond delays taken immediately after a seek.

#### 0.002258300 ← Settle delay loop time as tested.

Settle Delay, Cnt & Millisecs:			Rslt Times:
SettleCount:	0	Totl:	6.662
Delay time:	0.00	Wait:	6.612
Total calc. delay:			0.000
SettleCount:	1	Totl:	9.786
Delay time:	2.26	Wait:	9.699
Total calc. delay:			0.036
SettleCount:	2	Totl:	9.786
Delay time:	4.52	Wait:	9.661
Total calc. delay:			0.072
SettleCount:	4	Totl:	9.786
Delay time:	9.03	Wait:	9.590
Total calc. delay:			0.145
SettleCount:	8	Totl:	9.786
Delay time:	18.07	Wait:	9.450
Total calc. delay:			0.289
SettleCount:	16	Totl:	9.786
Delay time:	36.13	Wait:	9.160
Total calc. delay:			0.578
SettleCount:	32	Totl:	9.786
Delay time:	72.27	Wait:	8.595
Total calc. delay:			1.156
SettleCount:	64	Totl:	9.786
Delay time:	144.53	Wait:	7.457
Total calc. delay:			2.313
SettleCount:	80	Totl:	9.785
Delay time:	180.66	Wait:	6.890
Total calc. delay:			2.891
SettleCount:	88	Totl:	9.785
Delay time:	198.73	Wait:	6.605
Total calc. delay:			3.180
SettleCount:	90	Totl:	9.786
Delay time:	203.25	Wait:	6.536
Total calc. delay:			3.252
SettleCount:	91	Totl:	12.776
Delay time:	205.51	Wait:	9.490
Total calc. delay:			3.288
SettleCount:	92	Totl:	12.975
Delay time:	207.76	Wait:	9.658
Total calc. delay:			3.324
SettleCount:	120	Totl:	12.978
Delay time:	271.00	Wait:	8.650
Total calc. delay:			4.336
SettleCount:	128	Totl:	12.976
Delay time:	289.06	Wait:	8.376
Total calc. delay:			4.625
SettleCount:	255	Totl:	16.164
Delay time:	575.87	Wait:	7.040
Total calc. delay:			9.214

**Table 1:** Disk performance by head settle time



## SPEEDING MS DOS

(Continued from page 45)

To eliminate any noise in my data caused by losing interrupts during processing and the coarse granularity of the usual 18.2-tick-per-second interrupt clock, I coded a routine to access the AT high-resolution timer, which provides 1,024 interrupts every second. For those who are interested, Listing Two, page 95, is the

program used to access the AT clock.

The high-resolution timings confirmed the other results and also gave a more accurate figure for the delay loop as coded in the BIOS. Although the number of cycles in the delay instructions total approximately 1 millisecond of CPU time, because of cycle-stealing memory refresh and other perturbations, the actual time for one iteration of the loop is actually about 2.25 milliseconds. This

still could not account for the 3.5 seconds of performance improvement.

Next I moved the BIOS code down into RAM so patches could be made and breakpoints set: It was impossible to determine anything more from just timing the disk interrupt. I inserted a patch to time the subroutine that waits for the disk adapter to respond to the last command sent. This routine, called `WAIT_INT` in the BIOS, just loops until an interrupt is received from the adapter, after a command has been sent to the disk-controller chip.

### Results of My Tests

I performed 60 timing runs consisting of 20 different settle time parameters, run 3 times each. In each test I counted the overall time required to read the 16 cylinders and the total time spent in the `WAIT_INT` routine.

Table 1, page 45, shows the means of the times plotted against the head settle time as specified in the parameter block and as calculated according to my 2.25-millisecond figure for the delay loop.

What is interesting to note in this table is that overall disk performance changes as a step function, not continuously, and the times are constant over a wide range. Note also that the `WAIT_INT` time decreases as the head settle time increases, so the result is constant except at the breakpoints of 2.26, 205.5, and 575.87 milliseconds of settle time.

Within each range, the longer BIOS delays after a seek, the less time it takes for `WAIT_INT` to receive the interrupt from the controller, until the delay time passes a certain threshold. What is happening at that threshold? If you examine the differences between each plateau, you will see that each jump in overall time is about 3 seconds. If you divide the differences by the number of seeks (16) then you get a figure (0.18, 0.19, and so on) suggestively close to the time it takes for a 300-RPM drive to make one revolution—0.2 seconds. The second jump in the step function occurs when the settling delay increases from 2 milliseconds to 205 milliseconds, also very suggestive.

From these results, I developed the hypothesis that the overall time is constant within each rotational period of the disk. If a 1-millisecond delay

Settle delay loop time as tested:  
0.002258

Settle Count:	Calc'd 1 Loop (Milliseconds)	Total Timed:	Result Waiting:	Calc'd 16*Days	
0	0.000	6.662	6.612	0.000	
1	2.258	9.786	9.699	0.036	BREAK POINT
2	4.517	9.786	9.661	0.072	
4	9.033	9.786	9.590	0.145	
8	18.066	9.786	9.450	0.289	
16	36.133	9.786	9.160	0.578	
32	72.266	9.786	8.595	1.156	
64	144.531	9.786	7.457	2.313	
80	180.664	9.785	6.890	2.891	
88	198.730	9.785	6.605	3.180	
90	203.247	9.786	6.536	3.252	
91	205.505	12.776	9.490	3.288	BREAK POINT
92	207.764	12.975	9.658	3.324	
94	212.280	12.970	9.330	3.396	
96	216.797	12.978	9.513	3.469	
104	234.863	12.978	9.223	3.758	
112	252.930	12.978	8.937	4.047	
120	270.996	12.978	8.650	4.336	
128	289.063	12.976	8.376	4.625	
174	392.944	16.166	9.666	6.287	BREAK POINT
255	575.867	16.164	7.040	9.214	
260	587.158	19.350	9.674	9.395	BREAK POINT
346	781.372	22.141	9.283	12.502	BREAK POINT

\* Analysis of breakpoints:

Mean	6.662	Delta		Settle	0.000	Delta	
Total	9.786	in	0.195	time	0.002	in	
Time	12.951	Total	0.198	delay	0.206	Delay	0.203
for	16.165	Times,	0.201	for	0.393	time:	0.187
break-	19.350	per tk:	0.199	Major	0.587		0.194
points:	22.141		0.174	Breaks:	0.781		0.194
	>> Mean:		0.193		>> Mean:		0.195

#### Disk stats:

RPM: 300  
RPS: 5  
SPR: 0.200  
(Seconds per rev.)

#### Revolutions per head settle delay:

0.002 0.011 = 0  
0.206 1.028 = 1  
0.393 1.965 = 2  
0.587 2.936 = 3  
0.781 3.907 = 4

**Table 2:** Disk I/O speeds, 16-cylinder reads with different head settle time delay parameters



is taken immediately after a seek operation, subsequent processing must wait a full rotation before continuing. No further degradation occurs with increased delays until the delay equals or exceeds the rotational period, at which time processing time increases again by the rotation rate. The longer the BIOS waits for head settling, the less time `WAIT_INT` waits for the rotation of the disk to complete.

The data in Table 1, page 45, is inconclusive, however, because there is no entry for 400+ milliseconds and beyond: The interval between 2 and 204 milliseconds alone is not enough to prove the theory, and the test at 575 milliseconds has increased the delay too much to verify the 200-millisecond period.

Table 2 shows the results of additional tests that confirmed the hypothesis. If you examine the table, you will see that the jump from 12.9 to 16.1 seconds of processing time occurs at just about 400 milliseconds and from 16.1 to 19.3 at 600 milliseconds. Final confirmation is given by the jump at 781 (close enough to 800) milliseconds. Intervening data points in the 600- to 800-millisecond range are omitted, but timings showed the same plateaus as the other data.

Now we can see why DOS "can reach and sustain an input rate of one track per disk rotation." The trick is that by skipping the head settle delay altogether, there is no wait for an additional rotation of the disk and no latency degradation. One millisecond of delay is enough to force the controller to wait for another 200 milliseconds before the operation can complete.

#### Other Points

Returning to other points in Cortesi's column, it was simple to check more thoroughly into the problem of BASIC and disk I/O as outlined in the article. I found that indeed, as Cortesi writes (it's even documented in the manual), BASIC uses a default disk buffer size of 128 bytes. Increasing the buffer size can be done with a command-line switch: To specify a 1,024-byte disk buffer, the command is `BASIC /S:1024`.

I tried the test program with a buffer size of 8,192 bytes, and BASIC took only 10+ seconds to perform its DOS functions, as opposed to 44 sec-

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## SPEEDING MS DOS (Continued from page 47)

onds with a 128-byte buffer. Because BASIC uses DOS for its file I/O, forcing the head settle time to 0 had no effect: The minimum value is in effect whenever DOS performs BIOS disk read calls.

All these results can be summarized as follows. First, there is no mystery, magic, or extraordinary cleverness involved in how DOS handles disk I/O, and it certainly uses the ROM BIOS. The magic goes away when all the facts are in, although there are new problems to solve.

According to my findings, when performing file I/O through DOS, you can expect the best performance when you read a block size of more than C000h bytes. DOS reads blocks almost an entire segment (64K) at a time when you use the COPY command. Why settle for less (no pun intended) if you have the memory?

When writing your own BIOS disk handlers using interrupt 13h, set the head settle time to 0 for all read operations. It must be longer for write operations, but you can ignore the overall impact the settling time will have on performance because you will catch the latency delay of 200 milliseconds. Use the documented required values for write head settling times. This has no effect when file I/O is performed through DOS because DOS takes care of the settling time parameter already.

You can, however, shave additional seconds from both your own disk I/O and DOS's with the motor-start-delay parameter: Reduce this value to the minimum value that does not cause errors when you first access the disk. (I found no problems with a start-up delay of 0.) Listing Three, page 100, shows you how to set the head settle time and motor start-up delay in an assembly-language program.

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(Listing begins on page 94.)

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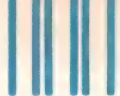
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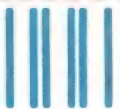
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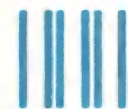
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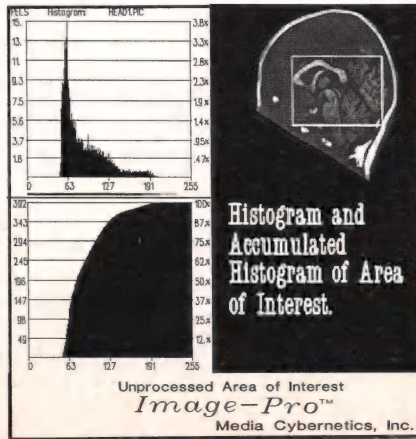
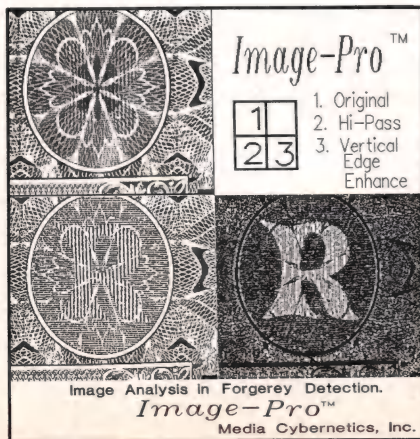
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# Automatic Porting Between Pascal Dialects

by Michael J. Sorens

***DIALATE converts one dialect of Pascal to another, provided programs are written according to the guidelines.***

In the course of programming events, some people have found it necessary to write Pascal code that could be ported between dialects of Pascal that differ from machine to machine. This task cannot be accomplished just by writing "vanilla" code to a maximal degree, as there are inevitably syntactical and semantic differences between dialects. At QCAD, we have developed a technique that, in conjunction with vanilla code, allows translation from one dialect to another to be performed automatically. Generally, when a file of program text needs to be translated to a new dialect, it also needs to be transmitted to a physically separate computer, and so our translation utility exists in two forms: a stand-alone translation utility and a combination translation/transmission utility.

## ***Finding the Denominator***

The primary task is to reduce functions and procedures to common denominators—that is, if a function does not exist in one dialect, it must be written for that dialect using the dialect's own primitives. This could be a simple renaming. Consider the following two functions, for example:

Turbo Pascal:

```
copy(string, location, length)
```

VAX Pascal:

```
substr(string, location, length)
```

As it happens, these functions are semantically identical, only the names have been changed to confuse the unwary. If we have written some code in Turbo Pascal, then we simply create a *copy* function for VAX Pascal:

```
function copy(STR: string255;
  WHERE, LEN: integer): string255;
begin
  copy := substr(str, where, len);
end;
```

Thereafter, we can use the *copy* function in either Turbo Pascal or VAX Pascal. Of course, we want the above definition of *copy* to exist only in the VAX environment because it will generate compilation errors in Turbo; we will see how to selectively compile this kind of entity shortly.

A second case might be this: In evaluating a logical expression, HP Pascal, for example, has a compiler option to do only partial evaluation (à la C) in which an expression is evaluated only until the point at which its result is determinable. C programmers use this to establish and avoid side effects. (It is quite a useful thing to have, but, alas, having it in only one Pascal dialect makes life difficult.)

If the function *foo* changes some global variable *y*, for example, then (*false and foo(x)*) will not change *y* if the dialect uses partial evaluation. This is because of the way the Boolean AND operates. Both terms must be true for the conjunction to be true. Scanning from left to right, because the first term *false* is false, we do not need even to look at *foo(x)* to deter-

mine the result. Without the partial evaluation feature, *foo(x)* will always be evaluated, potentially yielding differing results.

A second example might be a test such as

```
while (count <= length(str)) and
      (str[count] = 'X') do ...
```

which is a valid statement with partial evaluation but can cause a run-time error without it. Why? Well, as long as *count* is less than or equal to the length of the string *str*, there is no problem. When *count* becomes one larger than the length of *str*, however, referencing *str[count]* may cause a run-time error, depending on whether range checking is enabled for a particular compiler.

Therefore, we must modify the code in which results might vary depending on whether partial evaluation is available. This could be done by introducing a two-step evaluation. That is, rather than *if (false and foo(x)) then ...*, we substitute *if false then if foo(x) then ...*, which guarantees an equivalent partial evaluation. The *while* loop requires introducing some ugliness. We need a Boolean variable—call it *done*—which we initialize to false. Then, the code might be

```
while (count <= length(str)) and
      (not done) do begin
  done := (str[count] = 'X');
  if not done then ...
```

The simple elegance and power of partial evaluation begins to shine through, no?

A more cumbersome reduction involves string comparisons. In HP Pascal or Turbo Pascal, you could compare strings *s1* and *s2* merely by interposing a relational operator—



for example,  $(s1 < s2)$  or  $(s1 = s2)$ . In VAX Pascal, however, only strings of the same length can be compared (not strings of the same maximal length but strings of the same length at the moment of comparison). Thus, we need to introduce an added functional level in all three Pascals so that the code can be identical. We create the function *StrCmp* (see Table 1, below). Then, if we have existing code that needs to be retrofitted, we must change occurrences of  $(s1 = s2)$  to  $(strcmp(s1, s2) = 0)$  and likewise for the other relational operators.

### Make That Code Disappear

At some point, there will be pieces of code that must be seen by one compiler but must be hidden from another. Enter DIALATE. DIALATE—a combination of the words *dialect* and *translate*—converts one dialect of Pascal to another, provided a program text file has been set up according to the guidelines about to be discussed.

We introduce a metanotation to be used in any Pascal we are interested in. This is just a notation that is in some sense “above” the Pascal code in that our translator will be looking only at the metanotation and not at the Pascal text itself. In our metanotation, we have metabrackets, which are the only constructs that DIALATE looks for:

```
{ @x } opening metabacket for
        dialect x
{ @ } closing metabacket
```

We use the curly braces { and } as the basis of our dialect notation because they already have the capability of hiding text from a Pascal compiler—the simple comment. DIALATE scans for comments that immediately begin with an @ symbol, indicating that the comment is a special, dialectic comment. Immediately following the @ can be one or more dialect designations. We currently use the following conventions:

T—Turbo Pascal (IBM PC)  
V—VAX Pascal (VMS)  
H—HP Pascal  
A—Apple Pascal (Macintosh)

Any piece of code that cannot run on all relevant machines must be surrounded by metabrackets. DIALATE

inserts and removes the right curly brace of the opening metabracket in a judicious manner so that the compiler “sees” only valid language constructs.

Let’s look at an example. Consider opening a file for input in Turbo Pascal and in HP Pascal:

```
Turbo Pascal:
  assign(MyFile, FileName);
  reset(MyFile);
HP Pascal:
  reset(MyFile, FileName);
```

Because there are significant differences, it is perhaps wise to create a procedure *OpenInputFile* that can be used in both Pascal dialects. Here is what the procedure will look like in Turbo Pascal:

```
(1) procedure OpenInputFile
    (var F: text;
     NAME: string80);
(2) begin
(3)   { @T }
(4)   assign(f, name);
(5)   reset(f);
(6)   { @ }
(7)   { @H }
(8)   reset(f, name);
(9)   { @ }
(10) end;
```

Examine the position of each of the curly braces carefully. Notice that in line 3 there is a } but that in line 7 there is not. Thus, lines 4 and 5 are *active code*, while line 8 is *passive code*. Lines 6 and 9 are closing metabrackets that never change. The { in line 6 begins a comment that hides the @ character, while the { in line 9 is ignored because it is already inside

a comment. Now let’s run the procedure through DIALATE, converting it to HP Pascal code:

```
(1) procedure OpenInputFile
    (var F: text;
     NAME: string80);
(2) begin
(3)   { @T }
(4)   assign(f, name);
(5)   reset(f);
(6)   { @ }
(7)   { @H }
(8)   reset(f, name);
(9)   { @ }
(10) end;
```

The only difference is that the / in line 3 has gone, and there is a new / in line 7. This has reversed the active and passive sections of code. Hence, to write a piece of automatically translatable code, decide which dialect you wish to write in and use the appropriate metabrackets.

The technique is extensible to multiple machines with a concise notation. Take, for example, a function to find the location of a pattern string within some other string. In Turbo Pascal and HP Pascal, this function is called *pos*, while in VAX Pascal it is called *index*. We could then write a compatibility function called *index* to be used in Turbo or HP Pascal or one called *pos* to be used in VAX Pascal. A third alternative, though, is to write a function with a new name, perhaps *LocateSubString*, to be used in all three languages. Stylistically, it might be better to use a very different name so that there is no chance of confusing the name with some other valid language construct. As it hap-

```
function StrCmp(S, T: string80): integer;
{ return -1 if s<t; 0 if s=t; 1 if s>t }
var Result: integer;
begin
  if length(s) < length(t) then begin
    result := StrCmp(s, copy(t, 1, length(s)));
    if result = 0 then StrCmp := -1 else StrCmp := result
  end
  else if length(s) > length(t) then begin
    result := StrCmp(copy(s, 1, length(t)), t);
    if result = 0 then StrCmp := 1 else StrCmp := result
  end
  else if s = t then StrCmp := 0
  else if s < t then StrCmp := -1
  else if s > t then StrCmp := 1
end;
```

**Table 1**



## PASCAL PORTING

(Continued from page 51)

pens, the functions *pos* and *index* do precisely the same thing, though their parameter order is different, so we do not have to write much code.

```
(1) function LocateSubString
    (Object,
     Target: string80): integer;
(2) begin
(3)   { @HT
(4)   LocateSubString :=
        pos(object, target);
```

```
(5)   { @ }
(6)   { @V }
(7)   LocateSubString :=
        index(target, object);
(8)   { @ }
(9) end;
```

We can see that the above function is written in VAX Pascal because line 7, the VAX code, is active. Line 4 is passive code that is for both the HP and the Turbo dialects because line 3 has both a *T* and an *H*. When translated to either of these dialects, line 4 becomes active, while line 7 becomes passive.

## Case in Point

One final twist has precipitated out of the Babel-like differences in Pascals, and that is the *else* clause of a *case* statement. Some Pascals, such as Turbo, use the keyword *else* to indicate any cases not explicitly enumerated. Other Pascals, such as VAX, HP, and Macintosh, use the keyword *otherwise*. We can certainly handle this discrepancy using our standard notation described in the previous section. A typical *case* statement might look like this:

```
case SelectionChar of
'R':   RunIt;
'P':   ProcessIt;
'E':   EditIt;
{ @T }   else           { @ }
{ @HVA } otherwise      { @ }
        writeln('Invalid selection
                    character);
end { case };
```

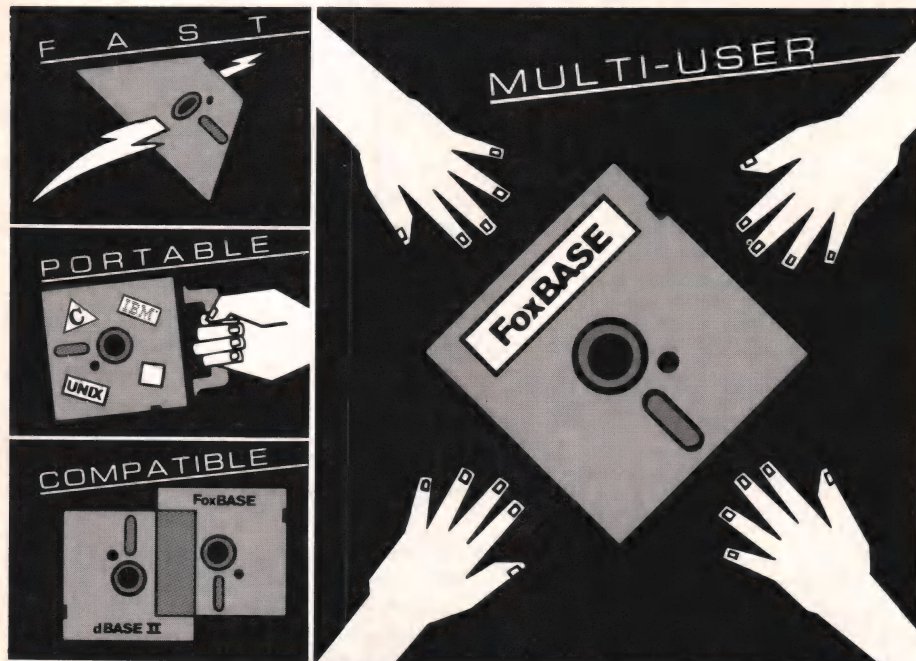
This can quickly become an annoyance, though. Because there is no way to make some kind of generic function that handles all *case* statements (as we did with *OpenInputFile*), we must use the metabracets every time we have a *case* statement. Or rather, we would have to if DIALATE didn't have a better solution.

What we would like to do is have the translator automatically convert an *else* to an *otherwise* if we are going from Turbo to either HP, VAX, or Macintosh Pascal and convert an *otherwise* to an *else* if we are going in the converse direction. But wait, what about the oft-found *if...then...else...statement*? How will we know if an *else* belongs to an *if* or to a *case*?

What we have chosen to do is have a special ELSE-OTHERWISE convention. In Turbo Pascal, we write *ELSE* to denote an *else* of a *case* statement and *else* to denote an *else* of an *if* statement. In our other Pascals, we write *OTHERWISE* to denote an *otherwise* of a *case* statement and *else* to denote an *else* of an *if* statement. That is, the *case* clause—whatever it is called—must be in uppercase letters, while the *if* clause must be in lowercase letters.

## Discussion

This dialect translation technique has minor disadvantages. The foremost is



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that you must have all metabracquets balanced and correct, otherwise you might hide too little or too much code from the compiler. This might cause compilation errors, but it also might not, possibly creating subtle bugs. If we accidentally made the VAX code above into passive code, for example, then the *LocateSubString* function would never be assigned a value. This could cause random or unpredictable results in the program. On the other hand, if we made both assignments active, a compiler should complain about the unknown function *index* or *pos*, depending on which machine the code is compiled. It takes a little getting used to, but typing correct metabracquets is, after all, no more difficult than typing correct syntax in a programming language.

Second, it is not possible to put actual comments inside a region that is metabracqueted. This may cause compilation errors when the entire region is supposed to be hidden because the closing comment bracket could inadvertently reactivate a portion of the hidden code. This is most insidious, however, when it does not cause compilation errors, as, for example:

```
procedure DUMMY;
begin
  { @H
  a := 10;
  b := 5;
  { @
  { @T }
  a := 5; { some global variables }
  b := 10;
  { @ }
end;
```

The above code, as written, will work fine with the Turbo compiler. When we translate it to run with HP Pascal, however, we will get the wrong value for *b* because the closing *}* of the "real" comment will prematurely close the comment created by the metabracquets.

The dialect translation technique discussed in this article is an effective and rapid way to work in several different Pascals with virtually the same program text. It may seem awkward at first, but you can readily get used to the style. And for those who need to work with more than one dialect or more than one machine, the tool may prove invaluable.

DIALATE was developed because of a perceived need at QCAD. We manufacture a large software package (a parser generator) that runs on the machines discussed above; DIALATE allows us to keep the same code on all the machines.

Should there be any readers who are so amazed by the technique revealed in this article (for the first time anywhere), I will gladly supply

both object and source code for DIALATE for a mere \$10.24 (a kilopenny) to cover diskette, postage, copying, and so on. I will also be happy to tell you about some of the neat software tools that QCAD sells for real money.

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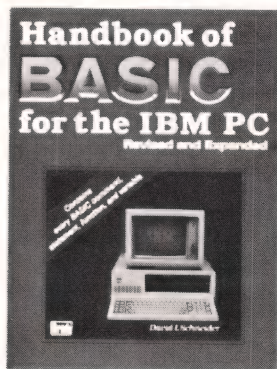
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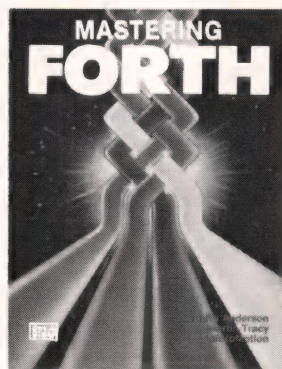


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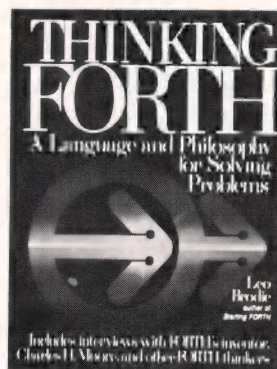
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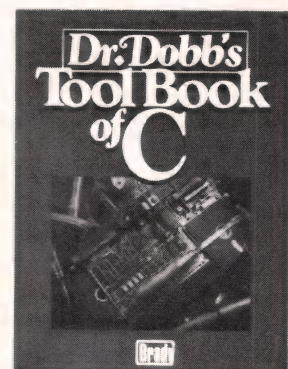
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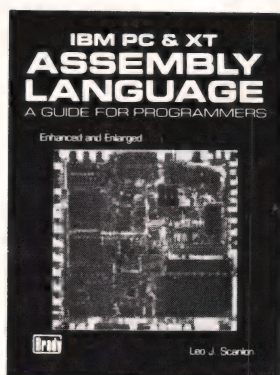
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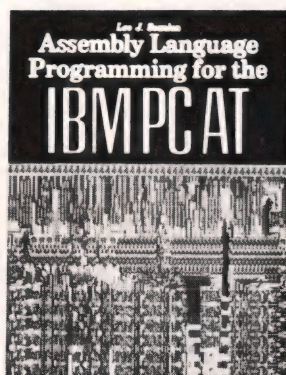
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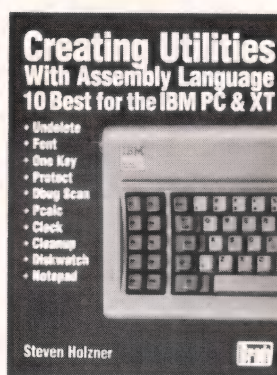
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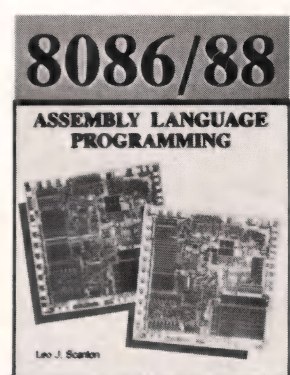
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# LETTERS

## LISTING ONE (Text begins on page 8)

```

/*****
/*
/*      Bose-Nelson Sort - Recursive Version
/*
/*      by R J Wissbaum
/*      15553 E Wyoming Dr - H
/*      Aurora, CO      80012
/*
/*      Reference:
/*      Dr. Dobb's Journal
/*      September 1985 (#107)
/*      Page 68
/*
/*
*****/

#include "STDIO.H"

int count = 0;

main ( argc, argv )
int argc,*argv;
{ int n;
  char arg[255];
  if ( argc < 2 )
    { printf ( "USAGE: bosesort n >outfile \n" );
      exit();
    }
  else
    { getarg( 1, arg, 255, argc, argv );
      n = atoi( arg );
      if ( n<0 ) n = -n;
      bosesort ( 2, 1, n, 0, 0 );
      printf ( "There were %d swaps \n", count );
    }
}

boresort( n, i, x, j, y )
int n, i, x, j, y;
{ int a, b;
  switch ( n )
    {
    case 0: { /* printf ( "\n" ); */
              break;
            }
    case 1: { /* printf ( "swap ( %d, %d ); \n", i, x ); */
              count++;
              break;
            }
    case 2: { if ( x != 1 )
                { a = ( x / 2 );
                  bosesort ( 3, i, a, (i+a), (x-a) );
                  bosesort ( 2, (i+a), (x-a), 0, 0 );
                  bosesort ( 2, i, a, 0, 0 );
                }
              break;
            }
    case 3: { a = ( x / 2 );
              if ( even ( x ) ) b = ( y + 1 ) / 2;
              else b = ( y / 2 );
              if ( ( x == 1 ) && ( y == 1 ) ) bosesort ( 1, i, j, 0, 0 );
              else if ( ( x == 1 ) && ( y == 2 ) )
                {
                  bosesort ( 1, i, j, 0, 0 );
                  bosesort ( 1, i, (j+1), 0, 0 );
                }
              else if ( ( x == 2 ) && ( y == 1 ) )
                {
                  bosesort ( 1, (i+1), j, 0, 0 );
                  bosesort ( 1, i, j, 0, 0 );
                }
              else if ( ( x != 0 ) && ( y != 0 ) )
                {
                  bosesort ( 3, (i+a), (x-a), j, b );
                  bosesort ( 3, (i+a), (x-a), (j+b), (y-b) );
                  bosesort ( 3, i, a, j, b );
                }
              break;
            }
    default: { printf ( "FATAL: Error in stack \n" );
                exit ();
                break;
            }
  } /* End of WHILE loop */
} /* End of BOSESORT */

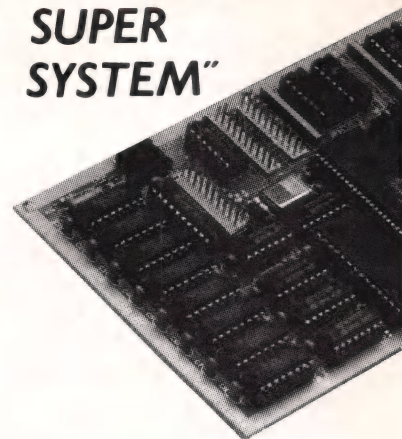
even ( x )
int x;
{ return ( 1 - ( 1 & x ) ); }

```

End Listing

Byte Magazine called it.

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# C CHEST

## LISTING SIX (Text begins on page 14)

```

1 char *skipto( c, p, esc )
2 register char *p ;
3 register int c, esc ;
4 {
5     /* Skip to c or to end of string. If c is preceded by
6      * the esc character it is skipped over.
7     */
8
9     while( *p && *p != c )
10    {
11        if ( *p != esc )
12            p++ ;
13
14        else if ( *p == esc ) /* skip over escaped characters */
15            p++ ;
16    }
17
18    return( p ) ;
19 }
```

End Listing Six

## LISTING SEVEN

```

1 /*
2  * DIR.H
3  * #defines and typedefs needed to talk to the routine dir().
4  * A pointer to the DIRECTORY structure is passed to dir().
5  * DIRECTORY structures are created by mk_dir() and deleted with
6  * del_dir().
7  *
8  * On entry:
9  *     dirv    is the first of an uninitialized array of character
10 *              pointers.
11 *     lastdir  should be initialized to point at dirv.
12 *     maxdirs  is the size of the above
13 *     nfiles   is the total file count, the total directory count
14 *     ndirs    and the total byte count. These will be incremented
15 *     nbytes   as appropriate and are usually set to 0 before
16 *              calling dir().
17 *     width    should be initialized to 0 before calling dir().
18 *     vol_label is undefined on entry to dir().
19 *     longf    is 1 if entries are to be printed in long format
20 *     files    is 1 if files are included in the list.
21 *     dirs     is 1 if directories are included in the list.
22 *     graphics is 1 if directories are highlighted with boldface.
23 *     hidden   is 1 if hidden files are to be included in the list.
24 *     path     is 1 if the path name is to be included in the list.
25 *     label    is 1 if you want to get the volume label
26 *     exp      is 1 if you want the contents of a subdirectory to
27 *              be listed rather than the directory name when. This
28 *              is only looked at if no wild cards are present in
29 *              the file spec.
30 *     sort     is 1 if you want the list sorted.
31 *
32 * all other fields are ignored. On exit the structure will have been
33 * updated as follows:
34 *
35 *     lastdir  will be incremented to point at the last entry added
36 *              to the dirv table.
37 *     maxdirs  will be decremented to reflect the added entries.
38 *     nfiles   is the number of added entries which are files.
39 *     ndirs    is the number of added entries which are directories.
40 *              Note that the equivalent of argc can be derived by
41 *              adding ndirs and nfiles together.
42 *     nbytes   will have the total size in bytes of all files added
43 *              to dirv. This number is the number of bytes actually
44 *              occupied by the file, i.e. the size returned by DOS
45 *              rounded up to the nearest multiple of the disk's
46 *              cluster size.
47 *     vol_label will hold the volume label provided that "label" was
48 *              set on entry.
49 *     width    will hold the length of the widest entry added to dirv
50 *
51 * all other fields will have the same values they had on entry.
52 */
53
54 typedef struct
55 {
56     char **lastdir ; /* Most recent addition to dirv */
57     int maxdirs ; /* # of free slots in dirv */
58     int nfiles ; /* # of used slots which are files */
59     int ndirs ; /* # of used slots that are directories */
60     long nbytes ; /* byte count of files */
61     char vol_label[12] ; /* volume label if requested */
62 }
```



```

64 unsigned width : 7 ; /* Width of widest element in dirv */
65
66 /* Various flags control how dir works: */
67 unsigned longf : 1 ; /* Use long format for entries */
68 unsigned files : 1 ; /* Include files in list */
69 unsigned dirs : 1 ; /* Include directories in list */
70 unsigned graphics : 1 ; /* Use graphics around directory names */
71 unsigned hidden : 1 ; /* List hidden files */
72 unsigned path : 1 ; /* List complete path if given */
73 unsigned label : 1 ; /* Load vol label with volume label */
74 unsigned exp : 1 ; /* Expand sub-directories */
75 unsigned sort : 1 ; /* Sort added entries */
76
77 char dirv[1]; /* The first of the dirv entries */
78 }
79 DIRECTORY;

```

End Listing Seven

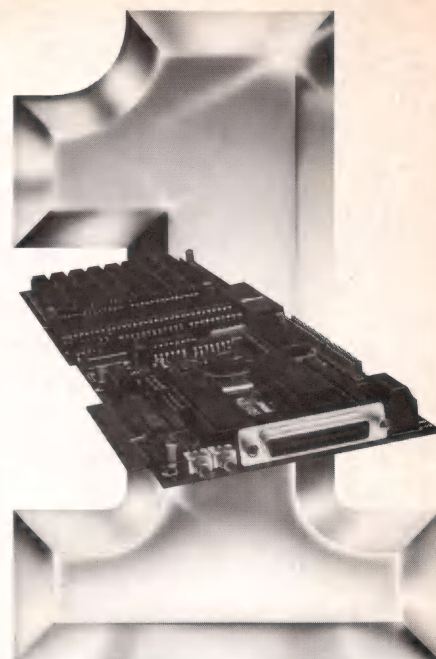
## LISTING EIGHT

```

1 #include <stdio.h>
2 #include <getargs.h>
3 #include <mydos.h>
4 #include <dir.h>
5
6 /*-----
7  * DIR.C: An MSDOS directory access function.
8  *
9  * (c) Copyright 1985, Allen I. Holub. All rights reserved.
10 *-----
11 * 11/22/85 Modified so that the total amount of disk space used
12 * (ie. # of clusters) is put into the total, rather
13 * than the file size.
14 *-----
15 */
16
17 /* ROUND(n,u): if n is an even multiple of u, evaluate to n, else
18 * round n up to the next even multiple of u.
19 */
20
21 #define ROUND(n,u) ( ((n) % (u)) ? (n) : ((n) / (u)) + 1 ) * (u)
22
23
24 #define BOLDFACE "\033[1m" /* Ansi esc sequence to turn bold face on */
25 #define ALL_OFF "\033[0m" /* attributes off */
26
27 #define ATTRIBUTES (READONLY | DIRTY | SYSTEM | HIDDEN | SUBDIR)
28 #define iswhite(c) ((c) == ' ' || (c) == '\t')
29
30 /*-----
31
32 extern char *calloc (unsigned,unsigned); /* In standard library */
33 extern char *cptolower(char*,char*); /* In /src/tools/cptolow.c */
34 extern char *cpy (char*,char*); /* In /src/tools/cpy.c */
35 extern int dos (REGS *); /* In /src/tools/dos.asm */
36 extern void gregs (REGS *); /* In /src/tools/dos.asm */
37 extern char *malloc (unsigned); /* In standard library */
38 extern char *next (char**,int,int); /* In /src/tools/next.c */
39 extern void ssort (char*,int,int,int(*) ()); /* In /src/tools/ssort.c */
40 extern int strcmp (char*,char*); /* In standard library */
41
42 /*-----
43
44 static unsigned Longfmt = 0; /* True if we're using long format. This
45 * has to be global for the comparison
46 * routine used for sorting to work.
47 */
48
49 static unsigned Cluster_size; /* Number of bytes per cluster on
50 * requested disk.
51 */
52
53 /*-----
54 /* Do a DOS system call using the dos() routine */
55
56 #define DOSCALL(id,regs) { regs.h.ah = id ; dos (&regs) ; }
57
58 /*-----
59
60 static int find_first( filespec, attributes, regp )
61 char *filespec ;
62 short attributes;
63 register REGS *regp;
64 {
65 /* Get directory information for the indicated file.
66 * Ambiguous file references are ok but you have to use
67 * find next to get the rest of the file references.
68 * In this case, The regs structure used by find_first
69 * must be passed to find next. 0 is returned on success,
70 * otherwise the DOS error code is returned.
71 */
72

```

(Continued on next page)



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# C CHEST

## LISTING EIGHT (Listing continued, text begins on page 14)

```

73      regp->h.ah = (char) FINDFIRST ;
74      regp->x.dx = (short) filespec ;
75      regp->x.cx = attributes ;
76
77      return (int) ( (dos(regp) & CARRY) ? regp->x.ax : 0 );
78 }
79
80 /*-----*/
81
82 static int      find_next ( regp )
83 REGS      *regp;
84 {
85      /*      Get the next file in an ambiguous file reference. A
86      *      call to this function must be preceded by a
87      *      find_first call. The regp argument must be the
88      *      same register image used by the find first call.
89      *      0 is returned on success, otherwise the error code
90      *      generated by DOS is returned.
91      */
92
93      regp->h.ah = FINDNEXT ;
94      return (int) ( (dos(regp) & CARRY) ? regp->x.ax : 0 );
95 }
96
97 /*-----*/
98
99 int      haswild(s)
100 register char *s;
101 {
102      /*      Return true if s has a unix wild card in it.      */
103
104      for( ; *s ; s++)
105          if( *s == '*' || *s == '?' )
106              return 1;
107      return 0;
108 }
109
110 /*-----*/
111
112 static int      isrootdir( name )
113 register char *name;
114 {
115      /*      return true if name is explicitly specifying the root
116      *      directory (ie. is one of: d:/ d:\ / \ where
117      *      'd' can be any disk designator.
118      */
119
120      if( *name && name[1] == ':' )
121          name += 2;
122
123      return( (*name == '\\') || (*name == '/') && !name[1] );
124 }
125
126 /*-----*/
127
128 has_only( str, inclusion_set )
129 register char *str;
130 char *inclusion_set;
131 {
132      /*      Return true only if every character in str is also in
133      *      inclusion_set. True is returned if str is empty.
134      */
135
136      register char *p;
137
138      for( ; *str ; str++)
139      {
140          for( p = inclusion_set ; *p && *p != *str ; p++ )
141              ;
142
143          if( !*p )
144              return 0;
145      }
146      return 1;
147 }
148
149 /*-----*/
150
151 static char *fixup_name( name, regs, info )
152 register char *name;
153 REGS *regs;
154 FILE_INFO *info;
155 {
156      /*      If the name specifies an implicit file (ie. it asks for
157      *      the directory rather than the files in the directory),
158      *      modify it to ask for files (eg. "." becomes "..\*.**").
159      *      If the name is actually modified, a pointer to a modified
160      *      copy of the original name is returned. Otherwise the
161      */

```



```

162      * original buffer is returned.
163      */
164
165      static char   buf[80] ;           /* Place to put modified name */
166      register char *p = buf ;          /* Always points into buf      */
167      char          *start_name = name; /* Remember start of name      */
168
169      if( isrootdir(name) || (name[0] && name[1]!=':' && !name[2]) )
170      {
171          /* Handle an explicitly requested root directory or
172           * the current directory on another disk.
173           */
174
175          sprintf(buf, "%s*.*", name );
176      }
177      else if( !find_first( name, ALL, regs ) )
178      {
179          /* Look for the indicated name & see if it's a directory.
180           * If so, append slash-*. to the requested name
181           */
182
183          if( !IS_SUBDIR(info) )
184              return name;
185          else
186              sprintf(buf, "%s/*.*", name );
187      }
188      else
189      {
190          /*      If we get here then a non-existent file or directory
191           *      was requested.
192           *      If the name consists of nothing but the characters
193           *      \ / . or a drive designator, assume that the root
194           *      directory was requested and adjust the name
195           *      accordingly.
196           */
197
198          if( *name && name[1] == ':' ) /* Copy drive designator if */
199          {                             /* one's present.          */
200              *p++ = *name++;
201              *p++ = *name++;
202          }
203
204          if( has_only(name, ".\\\/") )
205              strcpy( p, "/*.*" );
206          else
207              return( start_name );
208      }
209
210      return( buf );
211 }
212
213 /*-----*/
214
215 static int dirtoa( target, infop, graphics, pathname )
216 register char *target ;
217 char          *pathname ;
218 register FILE_INFO *infop ;
219 unsigned      graphics;
220 {
221     /*      Convert directory entry held in infop to an ascii string
222     *      in target. If Longfmt use a long format, if graphics then
223     *      directory names are printed in bold face, else they're
224     *      printed as "<name>." If pathname is true then the name
225     *      will be preceded with the full pathname.
226     */
227
228     char *startstr = target;
229     int i;
230
231     if( Longfmt )
232     {
233         *target++ = ( IS_READONLY(infop) ) ? 'r' : '.' ;
234         *target++ = ( IS_HIDDEN  (infop) ) ? 'h' : '.' ;
235         *target++ = ( IS_SYSTEM  (infop) ) ? 's' : '.' ;
236         *target++ = ( IS_SUBDIR  (infop) ) ? 'd' : '.' ;
237         *target++ = ( IS_DIRTY   (infop) ) ? 'm' : '.' ;
238
239         sprintf(target, " %6ld %2d/%02d/%02d %2d:%02d:%02d - ",
240                 infop->fi_fsize,
241                 C_MONTH(infop), C_DAY(infop), C_YEAR(infop)-1900,
242                 C_HR(infop), C_MIN(infop), C_SEC(infop) );
243
244         while( *target )
245             target++;
246     }
247
248     if( IS_SUBDIR(infop) && graphics )
249         target = cpy( target, BOLDFACE );
250
251     target = cpy      ( target, pathname );
252     target = cptolower( target, infop->fi_name );
253
254     if( IS_SUBDIR(infop) && graphics )
255         target = cpy( target, ALL_OFF );
256
257     return( target - startstr );

```

(Continued on next page)



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# C CHEST

## LISTING EIGHT (Listing continued, text begins on page 14)

```

258 }
259
260 /*-----*/
261
262 static int      add_entry( infop, dp, path )
263 FILE_INFO      *infop ;
264 register DIRECTORY *dp ;
265 char            *path ;
266 {
267     /*      Add an entry to the DIRECTORY structure. Return 0 if
268     *      it was added, one if it wasn't.
269     */
270
271     char            buf[128] ;
272     register int    len ;
273
274     /*
275     *      If we're not printing hidden directories but the current
276     *      directory is nonetheless hidden, return immediately.
277     *      Similarly, return if the directory is full.
278     */
279
280     if( !dp->hidden && (IS_HIDDEN(infop) || *infop->fi_name == '.') )
281         return 1;
282
283     if( dp->maxdirs <= 0 )          /* No more room in dirv. return */
284         return 0;                  /* error status */
285
286     /*
287     *      Update the directory count or the file count as appropriate
288     *      return immediately if we're looking at a file and we aren't
289     *      supposed to list file. The same with directories.
290     */
291
292     if( IS_SUBDIR(infop) )
293     {
294         if( dp->dirs )
295             dp->ndirs++ ;
296         else
297             return 1;
298     }
299     else
300     {
301         if( dp->files )
302             dp->nfiles++ ;
303         else
304             return 1;
305     }
306
307     /*
308     *      Convert the FILE_INFO structure to an ascii string and put
309     *      it into buf. Then malloc a chunk of memory the correct size,
310     *      copy the ascii string there, and put the malloced memory
311     *      into dirv at the correct place.
312     */
313
314     Longfmt = dp->longf;
315
316     len = dirtoa( buf, infop, dp->graphics, path );
317
318     if( len > dp->width )
319         dp->width = len ;
320
321     if( *dp->lastdir = malloc(len + 1) )
322     {
323         strcpy( *dp->lastdir++, buf ) ;
324
325         /* Add file size to total. Note that the actual amount
326         * of space (# of clusters) used by the file on the
327         * disk is used.
328         */
329
330         dp->nbytes += ROUND( infop->fi_fsize, Cluster_size );
331
332         --dp->maxdirs;
333         return 1;
334     }
335
336     fprintf(stderr, "Can't get memory for directory\n");
337     return 0;
338 }
339
340 /*-----*/
341
342
343 static void      copy_path( dest, src )
344 char            *dest, *src;
345 {

```

(Continued on page 62)



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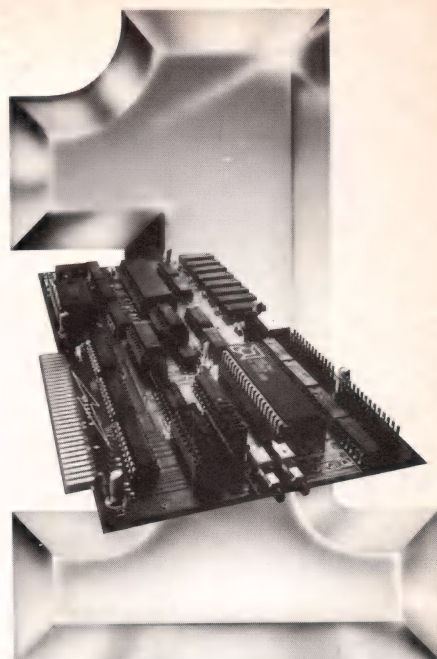
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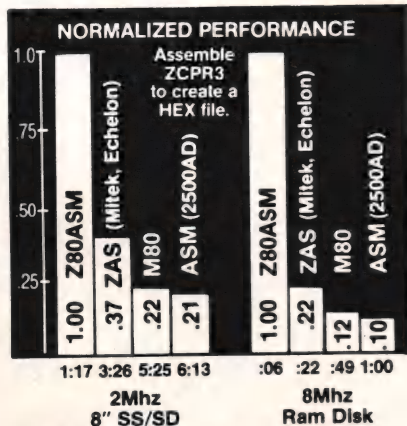
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# C CHEST

## LISTING EIGHT (Listing continued, text begins on page 14)

```

346      /*      Copy only the pathname part of the file spec contained in
347      *      src to dest. Path names longer than 64 characters are
348      *      truncated so dest must be at least 64 characters long.
349      */
350
351      register char  *p, *slash;
352
353      for( p = slash = src ; *p ; p++ )
354          if( *p == '/' || *p == '\\' || *p == ':' )
355              slash = p + 1;
356
357      for( p = src; p < slash && p - src < 64 ; *dest++ = *p++ )
358          ;
359
360      *dest = 0;
361 }
362
363 /*-----*/
364
365 static void  clab( dest, src )
366 register char  *dest, *src;
367 {
368     for( ; *src ; src++, dest++ )
369         if( *src != '.' )
370             *dest = *src ;
371 }
372
373 /*-----*/
374
375 static int  cmp( pp1, pp2 )
376 char  **pp1, **pp2;
377 {
378     /*      Comparison routine needed for ssort()      */
379
380     register char  *p1 = *pp1;
381     register char  *p2 = *pp2;
382
383     if( Longfmt )
384     {
385         /*      Skip forward to the '-' that will precede
386         *      the filename.
387         */
388
389         while( *p1 && *p1 != '-' )
390             p1++;
391
392         while( *p2 && *p2 != '-' )
393             p2++;
394     }
395
396     return( strcmp( p1, p2 ) );
397 }
398
399 /*-----*/
400
401 DIRECTORY  *mk_dir( size )
402 register unsigned size;
403 {
404     /*      Make a DIRECTORY with the indicated number of dirv entries.
405     *      Note that since one dirv entry is declared as part of the
406     *      DIRECTORY header, we'll actually have size+1 entries
407     *      available, though the last one is never used. We allocate
408     *      it so that we can terminate the list with a null
409     *      entry, even if the list is full.
410     */
411
412     register DIRECTORY  *dp;
413
414
415
416
417     if( !( dp = (DIRECTORY *)calloc( (unsigned)1,
418                                     sizeof(DIRECTORY) + (size * sizeof(char *)) ) ) )
419         return 0;
420
421     dp->maxdirs = size ;
422     dp->lastdir = (char **) dp->dirv;
423     return dp;
424 }
425
426 /*-----*/
427
428 del_dir( dp )
429 register DIRECTORY  *dp;
430 {
431     /*      Delete a directory made with a previous mk_dir call.
432     *      Note that all the strings pointed to by dirv entries
433     *      are assumed to have been gotten from malloc (this is
434     *      always true if dir() is used to fill the strings.

```

(Continued on page 66)



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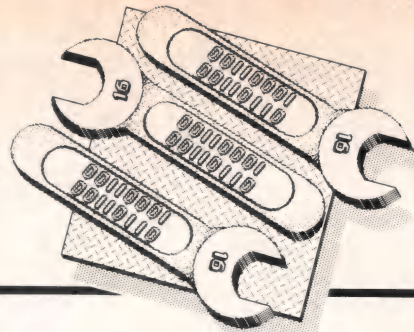
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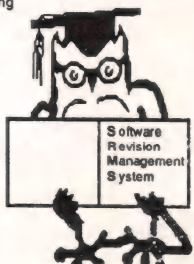
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## C CHEST

### LISTING EIGHT (Listing continued, text begins on page 14)

```

435      */
436
437      register char    **v;
438
439      for( v = (char **) dp->dirv; v < dp->lastdir ; free( *v++ ) )
440          ;
441
442      free( dp );
443  }
444
445  /*-----*/
446
447  dir( spec, dp )
448  char    *spec;
449  DIRECTORY *dp;
450  {
451      /*      Get a directory for the indicated spec. DOS wildcards are
452              permitted. If the DIRECTORY pointed to by dp already has
453              entries in it, new ones will be appended onto the existing
454              ones. If *spec is null, no files will be gotten, this is
455              useful if all you want is the volume label.
456
457              Note that the DTA is not modified by this routine. It
458              sets the DTA to its own address, but then restores the
459              DTA before returning.
460
461              REGS      regs      ;      /* Needed for DOS calls      */
462              FILE_INFO info      ;      /* DOS puts dirs here      */
463              char      path[80] ;      /* place to put path      */
464              char      **firstdir; /* Used for sorting      */
465              short     seg,off ;      /* Segment and offset of
466                                      /* original DTA
467
468              unsigned   sec_per_cluster, /* Used to compute number of
469                                      bytes_per_sector, /* bytes in a cluster
470                                      garbage;
471
472              gregs( &regs );      /* Get the original DTA      */
473              DOSCALL( GETDTA, regs );
474
475              seg = regs.x.es ;      /* remember it in set:off      */
476              off = regs.x.bx ;
477
478              regs.x.dx = (word) &info; /* Change the Disk Transfer Addr */
479              DOSCALL( SETDTA, regs ); /* to point at info structure */
480
481
482              /*      Find the number of bytes/cluster on the indicated
483                      * disk drive (or on the current drive if none is
484                      * specified.
485
486              if( !diskinfo( (!*spec||spec[1]!=':') ? 0 : (toupper(*spec)-'A')+1,
487                          &sec_per_cluster, &bytes_per_sector, &garbage) )
488                  fprintf(stderr, "dir: Can't access indicated disk\n");
489
490              Cluster_size = sec_per_cluster * bytes_per_sector ;
491
492
493              /*      If a volume label is requested, get it and copy it into
494                      * dp->vol_lab. Any imbedded '.'s are stripped by clab.
495                      * If no volume label is present, the string is nulled.
496
497              if( dp->label )
498              {
499                  *dp->vol_label = 0;
500
501                  if( spec[1] != ':' )
502                      strcpy( path, "/*.*" );
503                  else
504                  {
505                      *path = *spec ;
506                      strcpy( path+1, "/*.*" );
507                  }
508
509                  if( !find_first( path, LABEL, &regs ) )
510                      clab( dp->vol_label, info.fi_name );
511              }
512
513              /*      Now get the directories:
514
515              if( dp->exp && !haswild( spec ) )
516                  spec = fixup_name( spec, &regs, &info );
517
518              copy_path( path, dp->path ? spec : "" );
519
520
521
522
523

```

(Continued on page 68)

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Sieve	<b>21.0</b>	24.8	21.0	26.3	23.3
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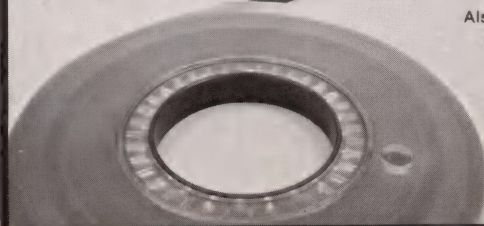
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## LISTING EIGHT (Listing continued, text begins on page 14)

```

524     firstdir = dp->lastdir;
525
526     /*      Now go look for the file:
527     */
528
529     if( !find first(spec, ATTRIBUTES, &regs) )
530         if( !add_entry(&info, dp, path) )
531             goto abort;
532
533     if( haswild(spec) )
534         while( !find next( &regs ) )
535             if( !add_entry(&info, dp, path) )
536                 goto abort;
537
538     if( dp->sort )
539         ssort( (char *)firstdir, dp->lastdir - firstdir,
540               sizeof(char*), cmp);
541
542 abort:
543     regs.x.ds = seg ;           /* Restore the original disk */
544     regs.x.dx = off ;           /* transfer address. */
545     DOSCALL( SETDTA, regs );
546 }

```

End Listing Eight

## LISTING NINE

```

1 #include <stdio.h>
2 #include <ctype.h>
3
4 #define MAXARGC      (unsigned)128
5 #define isquote(c)    ((c)=='"' || (c)=='\'')
6
7 extern char    *getenv( char* );
8 extern char    *malloc( unsigned );
9
10 /*-----*/
11
12 static char    *nextarg( pp )
13 char          **pp;
14 {
15     register char    *p;
16     char            *start;
17     register int      term;
18
19     if( !(p = *pp) )
20         return (char *) 0;
21
22     while( isspace(*p) )
23         p++;
24
25     if( isquote(*p) ) /* Can't use a conditional because */
26         term = *p++; /* of order of evaluation problems */
27     else
28         term = ' ';
29
30     for( start = p; *p ; p++)
31     {
32         if( *p == term && *(p-1) != '\\')
33         {
34             *p++ = '\\0';
35             break;
36         }
37     }
38
39     *pp = p;
40
41     return start;
42 }
43
44 /*-----*/
45
46 int    reargv( argcp, argvp )
47 char   ***argvp;
48 int    *argc;
49 {
50     register int    argc = 0 ;
51     register int    maxc = MAXARGC ;
52     char            **argv, **start_argv ;
53     char            *env, *p ;
54
55     if( !(env = getenv("CMDLINE")) || !*env )
56         return 0;
57
58     if( !(p = malloc( strlen(env)+1 )) )
59         return 0;

```

(Continued on page 70)



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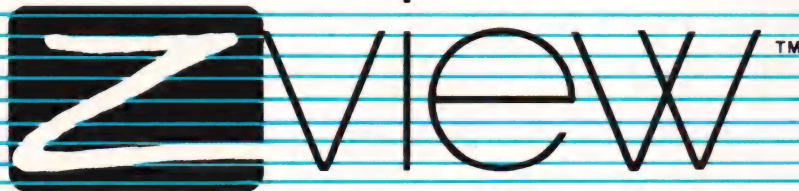
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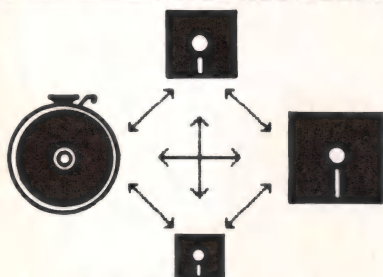
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## C CHEST

### LISTING NINE (Listing continued, text begins on page 14)

```

60
61     if( !(argv = (char **) malloc( MAXARGC * sizeof(char *) ) ) )
62         return 0;
63
64     strcpy(p, env);
65     start_argv = argv;
66     for( maxc=MAXARGC; --maxc >= 0 && (*argv++ = nextarg(&p)); argc++)
67         ;
68
69     if( maxc < 0 )
70         fprintf(stderr, "Command line truncated\n");
71
72     *argcp = argc;
73     *argvp = start_argv;
74     return 1;
75 }
76
77 /*-----*/
78
79 #ifdef DEBUG
80
81 main( argc, argv )
82 char **argv;
83 {
84     printf("Original command line is: |");
85     while( --argc >= 0 )
86         printf("%s|", *argv++ );
87
88     if( !reargv( &argc, &argv ) )
89         printf("\nCMDLINE not present\n");
90     else
91     {
92         printf("New argc = %d\n", argc );
93         printf("\nModified command line is: |");
94
95         while( --argc >= 0 )
96             printf("%s|", *argv++ );
97
98         printf("\n");
99     }
100 }
101
102 #endif

```

End Listing Nine

### LISTING TEN

```

1 /*      SSORT.C      Works just like qsort() except that a shell
2 *          sort, rather than a quick sort, is used. This
3 *          is more efficient than quicksort for small numbers of elements
4 *          and it's not recursive so will use much less stack space.
5 *
6 *          Copyright (C) 1985, Allen I. Holub. All rights reserved
7 */
8
9 void      ssort( base, nel, width, cmp )
10 char      *base;
11 int       nel, width;
12 int       (*cmp) ();
13 {
14     register int     i, j;
15     int              gap, k, tmp;
16     char             *p1, *p2;
17
18     for( gap = nel >> 1; gap > 0; gap >>= 1 )
19         for( i = gap; i < nel; i++ )
20             for( j = i-gap; j >= 0; j -= gap )
21             {
22                 p1 = base + ( j * width);
23                 p2 = base + ((j+gap) * width);
24
25                 if( (*cmp)( p1, p2 ) <= 0 )
26                     break;
27
28                 for( k = width; --k >= 0; )
29                 {
30                     tmp = *p1;
31                     *p1++ = *p2;
32                     *p2++ = tmp;
33                 }
34             }
35 }

```

End Listings



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- mv** Renames a file or directory. Moves files to another directory.
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# METRIC MINIMIZER

## LISTING ONE (Text begins on page 24)

```

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 * Global include file for the Variable Metric Minimizer program.
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 * This program may be reproduced for personal, non-profit use only.
 */

#define C80

/*
 * remove the above line if you are not using C/80
 */

#ifdef C80

/*
 * required for the Software Toolworks C/80 Version 3.0 compiler
 */

#define double float
#include "fprintf.h"
#include "scanf.h"

/*
 * the following is the <math.h> for C/80
 */

float sin(), cos(), atan(), sqrt(), exp(),
      pow(), powl0(), ln(), log(), fabs(), atof();

#else

/*
 * other compilers
 */

#include <stdio.h>
#include <math.h>
#include <ctype.h>

```

```

/*
 * ctype.h may be needed for an isspace used in read.c
 * some systems need it, some don't!
 * check your math.h for fabs and atof declarations!
 */

#endif

double dot();
struct bound
{
    int f1;
    double up;
    double lo;
    double ml;
};

struct xydata
{
    double x;
    double y;
};

#define BOUND DATA
#define VECMAX 10
#define MATMAX NEPS
#define STDES DFP
#define BFGS ALLDONE
#define NEGEDM BADMIN
#define BADLS MAXITERS
#define OK EDM1
#define EDM2 EDM2
#define TOOSML TOOSML

struct bound
struct xydata
2
2
0
1
2
-1
-3000
-2000
-1000
0
1000
2000
3000

```

End Listing One

(Continued on page 76)

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# METRIC MINIMIZER

## LISTING TWO (Listing continued, text begins on page 24)

```

/* VMM.C
 *
 * The main driver routine, function library routine
 * and all library functions for vmm.
 * (c) Copyright 1985, Billybob Software. All rights reserved.
 * This program may be reproduced for personal, non-profit use only.
 */

#include "global.h"

#define DMAX 50 /* Size of experimental data array */
#define NFUN 3 /* Num of functions in function library */

/*****

main()
{
    static int nparam ; /* number of parameters */
    static double const[VECMAX] ; /* constants used in function */
    static double param[VECMAX] ; /* parameters to be found */
    static double dstep[VECMAX] ; /* step sizes for derivatives */
    static double epsilon[VECMAX] ; /* stopping criteria */
    static BOUND limit[VECMAX] ; /* limits if constrained */
    static char *pname[VECMAX] ; /* parameter names */
    static double g0 ; /* expected value of minimum */
    static int debug ; /* debug level, 0 if off */
    static int itermin ; /* minimum number of iterations */
    static int iterlim ; /* maximum number of iterations */
    static int nreset ; /* reset y after this many iters */
    static DATA exp[DMAX] ; /* xy experimental data */
    static int npoints ; /* number of data points */
    static double *(*fun)() ; /* ptr to function to minimize */
    static int iters ; /* number of iterations it took */
    static int retcode ; /* return code from minimization */
    static double gmin ; /* the value at the minimum */
    static int method ; /* method used to update y */
    static int control ;
    int i, j ;

    for ( i=1 ; ; ++i )
    {
        raz ( &nparam , &itermin , &iterlim , &nreset , &debug ,
              limit , dstep , param , &g0 , epsilon , &method ) ;

        if ( (control = reader ( &fun , const , &nparam , param ,
                                limit , dstep , pname , epsilon , &itermin ,
                                &iterlim , &nreset , &g0 , &debug , exp ,
                                &npoints , DMAX , &method)) == ALLDONE )
            break ;

        if ( control )
            continue ;

        if ( ddefault ( nparam , &itermin , &iterlim , &nreset ,
                       epsilon , limit , dstep , debug ) )
            continue ;

        retcode = minim ( nparam , fun , param , dstep , limit ,
                          g0 , itermin , iterlim , epsilon , &gmin ,
                          &iters , debug , nreset , exp , npoints ,
                          const , method ) ;

        printf("\t*****\n") ;
        printf("\t* results from dataset %2d *\n", i ) ;
        printf("\t*****\n") ;
        printf("stopped after %ld iterations, ", iters ) ;

        switch ( retcode )
        {
            case NEGEDM : printf("negative e.d.m.\n") ; break ;
            case BADMIN : printf("new min > last min\n") ; break ;
            case BADLS : printf("line search failed\n") ; break ;
            case MAXITERS: printf("maximum iterations\n") ; break ;
            case EDM1 : printf("e.d.m. within tol.\n") ; break ;
            case EDM2 : printf("e.d.m. within tol.\n") ; break ;
            case TOOSML : printf("change too small\n") ; break ;
            default : printf("unknown reason!!!\n") ; break ;
        }

        printf("value of the minimum was %11.4e\n", gmin ) ;
        printf("parameter values at minimum:\n") ;
    }
}

```

(Continued on page 78)



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# METRIC MINIMIZER

## LISTING TWO (Listing continued, text begins on page 24)

```

        for (j=0 ; j<nparam ; ++j)
            printf("%15s %11.4e\n" , pname[j] , param[j]);

        printf("*****\n") ;
    }

    /*****
    *      Function library. Note that NFUN is #defined at the top of this
    *      module.
    */

    funlib ( funname , fun , np , nc , pname )
    char    funname[] ;          /* name of function to be minimized */
    int     *fun ;               /* address of function (non-portable) */
    int     *np ;                /* number of parameters in the function */
    int     *nc ;                /* number of constants in the function */
    char    *pname[] ;           /* parameter names vector */
    {
        /*
        * use funname to return fun and np, nc from a list
        * for each new function in the library, you must:
        *   (1) declare the function "double" and link it in the load module
        *   (2) declare the function below under "functions available"
        *   (3) add an entry in the function table, including parameter names
        *   (4) add an entry in the switch table in the code
        *   (5) update the value of NFUN
        *
        * Available functions are:
        */

        double    cohen() ;
        double    sinus() ;
        double    rosen() ;

        /*
        * function table
        */

        static struct
        {
            char *name ;          /* function name in funname call */
            int  nnpp ;           /* number of parameters in the function */
            int  nncc ;           /* number of constants in the function */
            char *ppnn[VECMAX] ; /* list of names for the parameters */
        } fctlib[NFUN] = {

            /* 0 */ { "cohen" , 2, 0 , "alpha" , "beta" , },
            /* 1 */ { "sine" , 4, 0 , "P0" , "P1" , "P2" , "P3" , },
            /* 2 */ { "rosen" , 10, 5 , "x1" , "x2" , "x3" , "x4" , "x5" ,
                    "x6" , "x7" , "x8" , "x9" , "x10" }

        } ;

        int      j, k;

        for ( j=0 ; j<NFUN ; ++j )
            if ( ! strcmp( funname , fctlib[j].name ) )
                break ;

        if ( j==NFUN )
            return( 1 ) ;

        *np = fctlib[j].nnpp ;
        *nc = fctlib[j].nncc ;

        for ( k=0 ; k < *np ; ++k )
            pname[k] = fctlib[j].ppnn[k] ;

        switch( j )
        {
            case 0 : *fun = cohen ; break ;
            case 1 : *fun = sinus ; break ;
            case 2 : *fun = rosen ; break ;
        }

        return( 0 ) ;
    }

    /*****/
    double cohen ( const , xx , data , npoints , user )
    double const[] ;          /* vector of constants used by this fcn */
    double xx[] ;             /* the current values of the vector x */

```

(Continued on page 80)



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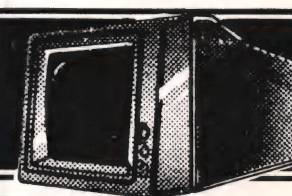
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# METRIC MINIMIZER

## LISTING TWO (Listing continued, text begins on page 24)

```

DATA    data[] ;          /* dummy                      */
int     npoints ;        /* dummy                      */
int     user ;           /* dummy, reserved for each user! */

{
    /*
     * computes the function to be minimized
     *
     * this is the test function given in Cohen, page 280
     * note that there are no constants for this fcn --
     * the vector const is included for compatability with other fcn
     *
     * note program calls function with user = 0
     */

    double t1 , t2 , t3 , t4 ;

    t1 = (xx[1] - xx[0]*xx[0]) ;
    t2 = t1 * t1 ;
    t3 = (xx[0] * (1.0 - xx[1]) + 1.0) ;
    t4 = t3 * t3 ;
    return ( t2 + t4 ) ;
}

/*****/

double sinus ( const , xx , data , npoints , user )
double const[] ;          /* vector of constants for this fcn */
double xx[] ;             /* parameter vector                */
DATA    data[] ;          /* data from file                  */
int     npoints ;        /* number of data points           */
int     user ;           /* user parameter                  */
{
    /*
     * extract parameters for polynomial fit to sine function
     */

    double t1 , t2 , t3 , t4 ;
    int i;

    for ( i=0 , t4 = 0.0 ; i<npoints ; i++ )
    {
        t1 = data[i].x * data[i].x ;
        t2 = data[i].x *
            (xx[0] + t1*(xx[1] + t1*(xx[2] + t1*xx[3])) ) ;
        t3 = (data[i].y - t2)/data[i].y ;
        t4 += t3 * t3 ;
    }

    return( t4 /= (double)(npoints-4) ) ;
}

/*****/

double rosen ( const , xx , data , npoints , user )
double const[] ;          /* vector of constants used by this fcn */
double xx[] ;             /* the current values of the vector x */
DATA    data[] ;          /* dummy                            */
int     npoints ;        /* dummy                            */
int     user ;           /* dummy, reserved for each user! */
{
    /*
     * Rosenbrock's test function
     */

    double t1 , t2 , t3 ;
    int l , m ;

    for ( l=0 , m=0 , t3 = 0.0 ; l<10 ; l += 2 , ++m )
    {
        t1 = xx[l] ;
        t2 = xx[l+1] ;
        t3 += const[m]*(t2-t1*t1)*(t2-t1*t1) + (1.0-t1)*(1.0-t1) ;
    }
    return( t3 ) ;
}

```

End Listing Two

## LISTING THREE

```

/* MINIM.C
 *
 * The main minimization routine
 * (c) Copyright 1985, Billybob Software. All rights reserved.
 * This program may be reproduced for personal, non-profit use only.
 */

#include "global.h"

```

(Continued on page 82)



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# METRIC MINIMIZER

## LISTING THREE (Listing continued, text begins on page 24)

```

/*****
minim ( n , fun , xextern , xstep , xlim , g0 , itermin , iterlim , epsilon ,
      gmin , iters , debug , nreset , data , npoints , const , method )

int    n ;                /* number of parameters in the fit          */
double (*fun)() ;         /* pointer to the function to minimize      */
double xextern[] ;        /* vector containing the starting values of
                           the parameters; returns values at minimum */
double xstep[] ;          /* step sizes on parameters for deriv calcs */
BOUND  xlim[] ;           /* limits on the vector x                  */
double g0 ;               /* expected value of the minimum of the fcn */
int     itermin ;         /* minimum number of iterations            */
int     iterlim ;         /* limit on the number of iterations        */
double  epsilon[] ;       /* iteration control parameters            */
double  *gmin ;           /* value of minimum for returned vector x   */
int     *iters ;          /* number of iterations to converge        */
int     debug ;           /* flag = 0 for no print, >0 for debug print */
int     nreset ;          /* reset limit for the y matrix             */
DATA    data[] ;          /* the data                                */
int     npoints ;         /* number of data points                   */
double  const[] ;         /* vector of constants required by fcn      */
int     method ;          /* update method for the matrix y          */
{
    /*
     * variable metric minimization algorithm
     * Reference (using DFP method) is:      Numerical Analysis
     *                                     A.M. Cohen et. al.
     *                                     Halstead Press
     *                                     John Wiley and Sons
     *                                     1973
     *                                     pages 276-280
     * See also original papers by Fletcher and Powell
     */

    int    i , j , rc ;
    static int    ycount ; /* counter for resetting the Y matrix */
    static double y[MATMAX] ; /* the Y matrix */
    static double a[MATMAX] ; /* the A and B matrices are calculated to */
    static double b[MATMAX] ; /* update the Y matrix at each iteration */
    static double xintern[VECMAX] ; /* parameters in internal coordinates */
    static double zint[VECMAX] ; /* gradients in internal coordinates */
    static double znewi[VECMAX] ; /* same for the next iteration */
    static double sigma[VECMAX] ; /* changes vector */
    static double s[VECMAX] ; /* changes direction vector */
    static double xi[VECMAX] ; /* change in gradient vector between
                                * iterations */
    static double xold[VECMAX] ; /* holds previous values of x */
    static double alpha ;
    static double g ; /* value of fcn for a given vector x */
    static double gnew ; /* likewise for the next iteration */
    double dot() ;

    /*
     * get started
     */

    g = (*fun)( const , xextern , data , npoints , 0 ) ;

    gozinta( n , xintern , xextern , xlim ) ;
    derivs ( n , fun , xintern , xstep , xlim , zint , data ,
            npoints , const , debug ) ;

    /*
     * main loop
     */

    for ( i = 1 , ycount = nreset ; i <= iterlim ; ++i , ++ycount )
    {
        if (ycount == nreset)
        {
            reset( n , y ) ;
            ycount = 0 ;
        }
        if (debug)
        {
            printf("\t\t\t+++++\n") ;
            printf("\t\t\t+ Begin iteration %2d +\n", i ) ;

```

(Continued on page 84)

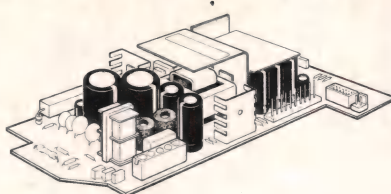


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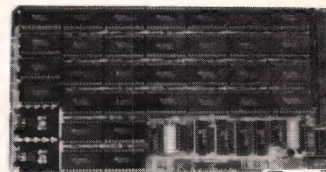
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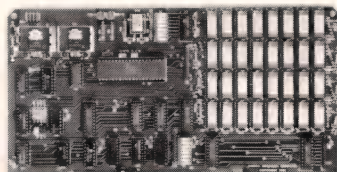


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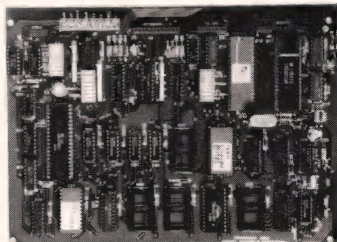
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## METRIC MINIMIZER

**LISTING THREE** (Listing continued, text begins on page 24)

```

printf("\t\t\t+++++\n") ;
printf("external parameter values are:\n") ;
vout( n , xextern ) ;
printf("internal parameter values are:\n") ;
vout( n , xintern ) ;
printf("internal gradient vector is:\n") ;
vout( n , zint ) ;
printf("approximate inverse hessian matrix is:\n") ;
mout( n , y ) ;
printf("the current minimum is --->%11.4e<---\n", g ) ;
}

matvec ( n , y , zint , s ) ;
for (j=0 ; j<n ; ++j)
{
    xold[j] = xintern[j] ;
    s[j] *= -1.0 ;
}

if (debug>1)
{
    printf("vector s is:\n") ;    vout( n , s ) ;
}

/*
 * do line search and quit if it fails
 * line search was successful if getalpha returns OK ( zero )
 */

if ( rc = getalpha ( n , fun , xintern , xstep , xlim , zint ,
    s , g , g0 , &alpha , debug , data , npoints , const ) )
    break ;

/*
 * update parameters
 */

for (j=0 ; j<n ; ++j)
{
    sigma[j] = alpha * s[j] ;
    xintern[j] += sigma[j] ;
}

if (debug>1)
{
    printf("vector sigma is:\n") ;    vout( n , sigma ) ;
}

/*
 * get values for next iteration
 */

gozouta ( n , xintern , xextern , xlim ) ;
gnew = (*fun)( const , xextern , data , npoints , 0 ) ;

derivs ( n , fun , xintern , xstep , xlim , znewi ,
    data , npoints , const , debug ) ;

for (j=0 ; j<n ; ++j)
    xi[j] = znewi[j] - zint[j] ;

if (debug>1)
{
    printf("orthogonality satisfied to %11.4e\n",
        dot ( n , znewi , sigma ) ) ;
    printf("vector xi is:\n") ;
    vout( n , xi ) ;
}

/*
 * decide whether to continue or not
 * continue if decide returns OK ( zero )
 */

if ( rc = decide( g , gnew , n , znewi , sigma , y ,
    epsilon , itermin , i , debug ) )
    break ;

/*
 * update all other quantities for the next pass

```

(Continued on page 86)



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# METRIC MINIMIZER

**LISTING THREE** (Listing continued, text begins on page 24)

```

* three methods available:
* steepest descent (slowest and included only for completeness)
* Davidon Fletcher Powell (default, empirically the favorite)
* Broyden Fletcher Goldfarb Shanno (thought to be better by
* some)
* The method is selected by keyword on input.
*/

if ( method == STDES )
    ; /* nothing to do, y is not updated */

else if ( method == DFP )
{
    dfpa ( n , sigma , xi , a , debug ) ;
    dfpb ( n ,   y   , xi , b , debug ) ;
    gety ( n ,   a   , b , y , debug ) ;
}
else if ( method == BFGS )
{
    bfgsa ( n , y , sigma , xi , a , debug ) ;
    bfgsb ( n , y , sigma , xi , b , debug ) ;
    gety ( n , a , b , y , debug ) ;
}

for (j=0 ; j<n; ++j)
    zint[j] = znewi[j] ;

gozouta ( n , xintern , xextern , xlim ) ;
g = gnew ;
/*
 * all done with this pass
 */
}

/*
 * outside of the main loop here
 */

*iters = ( i > iterlim ) ? iterlim : i ;

/*
 * first handle the case of abnormal exits
 * these have returned rc negative above, from either getalpha or decide
 */

if ( rc < 0 )
{
    for (j=0; j<n; ++j)
        xintern[j] = xold[j] ;
    gozouta ( n , xintern , xextern , xlim ) ;
    *gmin = g ;
}
else
{
    /*
     * regular exit and fall through These represent positive or
     * zero values of rc; zero means max iterations.
     */

    gozouta ( n , xintern , xextern , xlim ) ;
    *gmin = gnew ;
}

if (debug)
{
    printf("\t\t+++++\n") ;
    printf("\t\t+ exiting minimization +\n") ;
    printf("\t\t+++++\n") ;
    printf("\tnumber of iterations was: %lld\n",*iters) ;
    printf("\t\t\treturn code is: %lld\n",rc) ;
    printf("\t\t\t\t\tminimum is: %11.4e\n", *gmin) ;
    printf("best parameter values:\n") ;
    vout ( n , xextern ) ;
    printf("last internal gradient vector:\n") ;
    vout ( n , znewi ) ;
}
return( rc ) ;

```

### End Listing Three

**Listings to be continued next month**



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# CONCURRENCY

## LISTING ONE (Text begins on page 36)

```
{task #1: keyboard -> serial out
task #2: serial in -> video out
control-C will abort program}

program main;
const TASKS=2;
      STACKSIZE=70;
{next 7 constants are needed for the Kaypro}
      KDATA=5;
      KSTAT=7;
      BAUDP=0;
      SDATA=4;
      SSTAT=6;
      RMASK=1;
      TMASK=4;

      CC=3;
type stack = array[0..STACKSIZE] of integer;
tasknum = -1..TASKS;
var sp0,sp1,sp2: integer;{when zero, task not initialized}
oldn: tasknum;
nextn: tasknum;
Procedure defer; forward;
procedure exit;
begin
  writeln('TASK #',oldn,' terminated.');
```

```
key: byte;
begin
  stackptr:=addr(mystack[STACKSIZE]);
  repeat
    key:=keyin;
    if key=CC then exit
    else serout(key);
  until false;{forever}
  exit;
end;
```

```
Procedure task2;
var mystack: stack;
begin
  stackptr:=addr(mystack[STACKSIZE]);
  repeat
    videout(serin);
  until false{forever};
  exit;
end;
```

```
procedure initall;
var i: integer;
Begin
  sp1:=0;
  sp2:=0;
  oldn:=0;
  {initialize Kaypro's SIO}
  port[BAUDP]:=14;{9600 Baud}
  port[SSTAT]:=24;
  port[SSTAT]:=4;
  port[SSTAT]:=68;
  port[SSTAT]:=1;
  port[SSTAT]:=0;
  port[SSTAT]:=3;
  port[SSTAT]:=193;
  port[SSTAT]:=5;
  port[SSTAT]:=234;
end;
```

```
Procedure schedule;
begin
  if oldn=TASKS then nextn:=1
  else nextn:=oldn+1;
end;
```

```
procedure defer;
var sp: integer;
begin
  case oldn of
    0: sp0:=stackptr;
    1: sp1:=stackptr;
    2: sp2:=stackptr;
  end{case};
  schedule;
  oldn:=nextn;
  case nextn of
    0: sp:=sp0;
    1: sp:=sp1;
```

(Continued on page 90)

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# CONCURRENCY

## LISTING ONE (Listing continued, text begins on page 36)

```

2: sp:=sp2;
end(case);
if sp<0 {initialized}
then begin
  stackptr:=sp;
end
else {not initialized}
begin
  writeln('Starting task #',nextn);
  case nextn of
    1: task1;
    2: task2;
  end(case);
end;
end(defer);
begin(main)
  initall;
  writeln('Multitasking version of simple terminal program');
  writeln('Control-C will terminate it');
  writeln;
  defer;
  writeln('Main: done');
end.

```

**End Listing One**

## LISTING TWO

```

(task #1: keyboard -> fifol
 task #2: fifol -> filter -> fifo2
 task #3: fifo2 -> slow display )
program main;
const
  TASKS=3;
  STACKSIZE=20;
  NFIFOS=2; {#1 is for input and #2 for output}
  PRATE=300; {SLOWS the display function}
  {the following three constants are for the Kaypro Computer}
  KDATA=5; KSTAT=7; RMASK=1;
  CR=13;
  LF=10;
  CC=3;
  BS=8;
  RUB=127;
  SPACE=32;
  CQ=17; {XON}
  CS=19; {XOFF}
type
  stack = array[0..STACKSIZE] of integer;
  fifo = record
    buf: array[0..255] of byte;
    inptr: byte;
    outptr: byte;
    flow: boolean; {for flow control}
  end;
  fifon = 1..NFIFOS;
  tasknum = -1.. TASKS;
var
  sp0,sp1,sp2,sp3: integer; {when zero, task not initialized}
  oldn: tasknum;
  nextn: tasknum;
  fifos: array[1..NFIFOS] of fifo;
Procedure defer; forward;
function occupancy(p: fifon): byte;
begin with fifos[p] do
  occupancy:= inptr-outptr;
end;
function vacancy(p: fifon): byte;
begin with fifos[p] do
  vacancy:=outptr-inptr-1;
end;
function dequeue1: byte;
begin with fifos[1] do
  begin
    while (occupancy(1)=0) or not flow
      do defer;
    dequeue1:= buf[outptr];
    outptr:=outptr+1;
  end;
end;
function dequeue2: byte;
begin with fifos[2] do
  begin
    while (occupancy(2)=0) or not flow
      do defer;
    dequeue2:= buf[outptr];
    outptr:=outptr+1;
  end;
end;
procedure exit;

```

```

begin
  writeln('JOB #',oldn, ' terminated.');
```

```

  oldn:=1;
  defer;
end;
procedure enqueue1(b:byte);
begin with fifos[1] do
  begin
    buf[inptr]:=b;
    while vacancy(1)=0 do
      defer; {hang while full}
    inptr:=inptr+1;
  end;
end;
procedure enqueue2(b:byte);
begin with fifos[2] do
  begin
    buf[inptr]:=b;
    while vacancy(2)=0 do
      defer; {hang while full}
    inptr:=inptr+1;
  end;
end;
function keyin:byte;
begin
  repeat until (RMASK = (RMASK and port[KSTAT]));
  keyin:= port[KDATA];
end;
procedure vout(b:byte);
begin
  bdos(6,b);
end;
Procedure print;(task#3)
var
  mystack: stack;
  i: integer;
begin
  stackptr:=addr(mystack[STACKSIZE]);
  i:=0;
  {initialize fifo#2}
  with fifos[2] do
    begin
      outptr:=0;
      inptr:=0;
      flow:=true;
    end;
  repeat
    i:=i+1;
    if i=PRATE then
      begin
        begin
          i:=0;
          vout(dequeue2);
        end
        else
          defer;
      until false; {forever}
    exit;
  end;
Procedure keyboard;(task #1)
var
  mystack: stack;
  cb: byte;
begin
  stackptr:=addr(mystack[STACKSIZE]);
  {initialize fifo #1}
  with fifos[1] do
    begin
      inptr:=0;
      outptr:=0;
      flow:=true;
    end;
  repeat
    if (1 = (1 and port[KSTAT]))
    then
      begin
        cb:= port[KDATA];
        enqueue1(cb);
      end
      else
        defer;
    until false; {forever};
  exit;
end;
Procedure filter;(task #2)
var
  mystack: stack;
  b: byte;
begin
  stackptr:=addr(mystack[STACKSIZE]);
  repeat
    b:=dequeue1;
    case b of
      CR: begin

```

(Continued on page 93)



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Until then, you'll just have to....wait.



# CONCURRENCY

## LISTING TWO (Listing continued, text begins on page 36)

```

        enqueue2 (CR);
        enqueue2 (LF);
    end;
    LF: {ignore};
    CC: exit;
    BS, RUB:
    begin
        enqueue2 (BS);
        enqueue2 (SPACE);
        enqueue2 (BS);
    end;
    CQ: fifos[2].flow:=true;
    CS: fifos[2].flow:=false;
    else enqueue2 (b);
    end(case);
until false; {forever!}
exit;
end;
procedure initall;
var i: integer;
begin
    spl:=0;
    sp2:=0;
    sp3:=0;
    oldn:=0;
end;
Procedure schedule;
begin
    if oldn=TASKS then nextn:=1
    else nextn:=oldn+1;
end;
procedure defer;
var sp: integer;
begin
    case oldn of
        0: sp0:=stackptr;
        1: spl:=stackptr;
        2: sp2:=stackptr;

```

```

        3: sp3:=stackptr;
    end(case);
    schedule;
    oldn:=nextn;
    case nextn of
        0: sp:=sp0;
        1: sp:=spl;
        2: sp:=sp2;
        3: sp:=sp3;
    end(case);
    if sp>0 {initialized}
    then begin
        stackptr:=sp;
        end
    else {not initialized}
    begin
        case nextn of
            1: keyboard;
            2: filter;
            3: print;
        end(case);
        end;
    end(defer);
begin(main)
initall;
writeln('<Demonstration of multitasking with queues (FIFOs)>');
writeln;
writeln('Control-S stops output (you can still type ahead!');
writeln('Control-Q restarts output (you can see what you have
        typed ahead');
writeln('RUB or BACKSPACE will "undo" on screen the last
        letter');
writeln('Control-C terminates this program');
writeln;
defer;
writeln('main: done');
end.

```

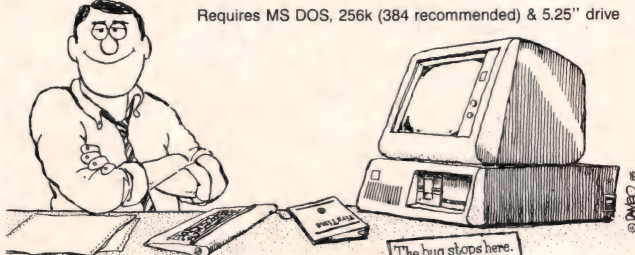
End Listings

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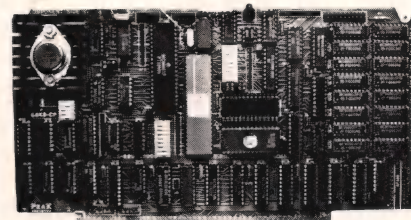


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# SPEEDING MS DOS

## LISTING ONE (Text begins on page 44)

```

;-----;
; Weissman/Dr. Dobbs submission Listing 1: ;
; Assembler BIOS diskette read test program. ;
;-----;

;-----;
; Assembler code to test diskette times, ;
; reading 16 tracks through INT 13. ;
; 10/1/85 Gregg Weissman ;
; E-X-E Software Systems ;
;-----;

HI_RES_TIMER equ 1

; Set this to 1 if you implement
; the 1024 tick/sec AT timer.
; It will return time in 1k'ths of
; a second. If using the usual IBM
; 18.2 ticks per second timer, set to 0
; and receive counts at that rate.

if HI_RES_TIMER

    GET_TIME equ 10h ; Define the proper AH function value
                    ; For int 1ah
else
    GET_TIME equ 0
endif

;-----;
; Start the test code: ;
;-----;

CODE segment
assume cs:code,ds:code,es:code,ss:code

    org 80h

TIME_LO dw ? ; Time accumulator out of the way.
TIME_HI dw ?

    org 100h

START: ;-----;
; First, read a dummy sector to start the ;
; diskette: this way motor start time will ;
; not affect the timings. ;
;-----;

    mov ax,0201h ; Read, 1 sector.
    mov cx,1 ; Starting @ track 0, sector 1
    mov dx,1 ; Side 0, diskette B:
    mov bx,offset DATA_AREA
    int 13h ; Perform the op.
    jnb STOP ; Error: abort.

;-----;
; Now, get the time of day and perform ;
; the test. Read 32 tracks, 16 cyl's. ;
;-----;

    cli
    mov ah,GET_TIME
    int 1ah
    mov TIME_LO,dx
    mov TIME_HI,cx
    sti
    xor bp,bp ; Set a register to count reads.
    mov di,290 ; number of sectors total in testfile.
    mov dx,1 ; disk B:
    mov cx,0001 ; Start at trk 0, sect 1
    mov bx,offset DATA_AREA

SIDE_1:
    mov al,9
    cmp di,al ; Number not mod 9, might do partial
    jnb N2 ; read on last track.
    mov ax,di ; Move partial read value into al

N2:
    mov ah,2 ; Read disk function code into AH
    int 13h ; Perform disk read.
    jnb STOP ; Error: don't bother with re-try.

    sub di,9 ; Subtract default count of sectors.
    jbe DONE ; We're done if di <= 0
    inc bp ; Count the op. to verify number done.

```



```

xor     dh,1           ; Flip sides.
jne     SIDE_1         ; If we flipped to side 1, do it.
inc     ch             ; else bump to next track (cylinder)
jmp     SIDE_1         ; and go back for more.

DONE:   mov     ah,GET_TIME ; OK, stop the clock.
        int     lah
        sub     dx,TIME_LO ; Get end_time - Start_time.
        sbb     cx,TIME_HI

STOP:   ; WARNING!
        ; This program does not return to DOS!
        ; Do not run this except under DEBUG!

        int 3          ; DEBUG breaks here, read time in DX
                        ; BP=20h and Carry Clear if no errors.

org     200h

DATA_AREA label byte

CODE    ends
end      START

```

**End Listing One**

## LISTING TWO

```

;-----;
; Weissman/Dr. Dobbs Submission. Listing 2: ;
; AT timer handler.                        ;
;-----;

;-----;
; Memory-resident handler for the 1024    ;
; tick/sec. realtime clock in the IBM AT: ;
;-----;
; Enables INT 70, the clock interrupt, and ;
; counts the ticks at the 1k rate. The range is ;
; 2**32 div 2**10, or 2**22 seconds. Long enough. ;

```

(Continued on next page)

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# SPEEDING MS DOS

## LISTING TWO (Listing continued, text begins on page 44)

```

;
; Sets up the usual INT 1A (Get/set time of day)
; to handle get/set of the hi-resolution timing
; data via special codes in AH register.
;
; With AH=10h, caller receives current time in 1k
; ticks.
; CX returns high 16 bits, DX the low.
; AH=11h allows user to set the 32-bit count.
; CX=High count to set, DX is low.
;
; 10/1/85 Written by Gregg Weissman
; E-X-E Software Systems
; Released to the public domain.
;-----;
CODE segment
assume cs:CODE,ds:CODE,es:CODE,ss:CODE

;-----;
; Conserve memory space: maintain variables
; in the unused areas of the program prefix.
;-----;

org 5ch

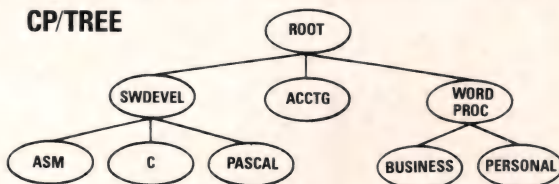
I1AJMP dd ? ; Vector to usual 1A int.
I70JMP dd ? ; Ditto the INT 70.
TIMELO dw ? ; low 16 bits of time.
TIMEHI dw ? ; Hi 16 bits of time.

org 100h ; Start of .COM program

BEGIN: jmp short START ; Jump around handlers.

```

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```

;-----;
; Handle the Get/Set time-of-day INT 1A: ;
; As mentioned, AH=10h Returns time, ;
; ;
; AH=11h Sets time ;
; Illegal values >11h return Carry status ;
;-----;

```

```

INT_1A proc far
assume ds:nothing, es:nothing, ss:nothing

```

```

cmp     ah,10h           ; See if it's our range of cmdnd vals.
jb      NOPE_1A          ; If less than, assume BIOS int 1a.
sub     ah,10h           ; Remove special code "bias" of 10h
je      GET_TIME         ; and branch if equal to "Get" cmdnd.
dec     ah               ; See if "Set" cmnds.
jne     BAD_CMD_1A       ; If not, branch to error.

```

```

;-- set time: cx,dx

```

```

mov     TIMEHI,cx
mov     TIMELO,dx
iret

```

```

GET_TIME:

```

```

mov     cx,TIMEHI        ; Obtain the number of times the 1024
mov     dx,TIMELO        ; tick per sec. interrupt has occurred.
iret

```

```

BAD_CMD_1A:

```

```

stc
ret     2                ; Return an error flag.

```

```

NOPE_1A:

```

```

jmp     I1AJMP           ; Continue to BIOS handler via vector.

```

```

INT_1A endp

```

(Continued on next page)

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# SPEEDING MS DOS

## LISTING TWO (Listing continued, text begins on page 44)

```

;-----;
; Handle the 1024 ticks/second realtime ;
; clock interrupt: maintain 32-bit count. ;
;-----;
; Still assume ds, etc. nothing in effect. ;
;-----;

INT_70 proc far

    push    ax
    push    ds
    mov     ax,cs
    mov     ds,ax

assume ds:CODE

    inc     TIMELO           ; Bump low counter.
    jne     CONT_70         ; Continue if count not wrapped around
    inc     TIMEHI           ; Bump high counter.

CONT_70:

    pushf
    call    I70JMP           ; Simulate INT nn
                           ; Call the realtime clock handler,
                           ; to let BIOS handle user-event-wait.
    call    ENABLE_INT       ; And return here so we can re-init
    pop     ds               ; the timer: BIOS turns it off.
    pop     ax
    iret

INT_70 endp

;-----;
; This routine enables the "PIE", or ;
; periodic interrupt event. It is called ;
; when the system initializes, and after ;
; each tick, in case BIOS turned it off. ;
;-----;
; This communicates with the CMOS ;
; module via ports 70h & 71h. The ;
; "JMP $+2" is for a delay between ;
; port accesses, allowing the device ;
; time to settle down. The 80286 is ;
; too fast. ;
;-----;

ENABLE_INT proc near

    cli                     ; Prevent interruption.
    mov     al,0bh           ; First, identify the reg.
    out     70h,al           ; we want (0b is the one).
    jmp     $+2              ; Just a long NOP.
    in      al,71h
    or      al,01000000b     ; This bit is int. enable
    mov     ah,al            ; Save value: we need al
    mov     al,0bh           ; Address the register again.
    out     70h,al
    jmp     $+2              ; NOP
    mov     al,ah            ; Get back the desired value.
    out     71h,al           ; Now stored in CMOS & ready.
    in      al,0alh          ; Int. control chip register.
    and     al,0feh          ; Bit 0 is another int. enable
    out     0alh,al          ; now set to allow interrupt.
    mov     al,20h          ; Send "End of interrupt" for
    out     0a0h,al          ; good measure.
    out     020h,al          ; ditto controller chip 1.
    sti
    ret

ENABLE_INT endp

;-----;
; Initialize the interrupt handlers and ;
; the interrupt generator itself. Leave ;
; behind the resident code. ;
;-----;
; We leave out amenities like DOS version ;
; test and check for an actual AT. ;
;-----;

START:
assume ds:CODE,es:CODE,ss:CODE

    mov     ah,10h           ; First check to see if already
    cld                     ; resident,
    mov     cx,1234h         ; by constructing an unlikely
    mov     dx,cx            ; time value of 12341234h
    int     1ah              ; See if we get the time back.
    cmp     cx,dx            ; If cx=1234=dx, not present.

```



```

je      NOT THERE
mov     dx,offset ALREADY      ; Tell the user it's in already
mov     ah,9                   ; using DOS print function.
int     21h
mov     ax,4c01h               ; Terminate with errorlevel 1
int     21h

```

NOT THERE:

```

mov     ax,3570h               ; Get the current vectors
int     21h                   ; from DOS.
mov     word ptr I70JMP,bx     ; Save in prefix are variables.
mov     word ptr I70JMP+2,es
mov     ax,351ah               ; Got the 70, now get 1A
int     21h
mov     word ptr I1AJMP,bx
mov     word ptr I1AJMP+2,es

push    cs                     ; Restore es for form's sake
pop     es

mov     THIS_SEG,cs

cli
mov     dx,offset INT_1a       ; Set interrupt vectors to our handlers
mov     ax,251ah
int     21h
mov     dx,offset INT_70       ; Ditto for int 70.
mov     ax,2570h
int     21h
mov     dx,offset HELLO        ; Print a message
mov     ah,9
int     21h

call    ENABLE_INT             ; Start the timer.

mov     dx,offset START+15     ; Set terminate address in
mov     cl,4                   ; paragraphs, rounding up &
shr     dx,cl                  ; dividing by 16.

mov     TIMELO,0               ; Clear the current time.
mov     TIMEHI,0

mov     ax,3100h               ; Terminate & stay put.
int     21h                   ; End.

```

(Continued on next page)

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# SPEEDING MS DOS

## LISTING TWO (Listing continued, text begins on page 44)

-- Messages for the user:

```
HELLO db 'Hi-resolution AT timer now loaded.',13,10,'$'
ALREADY db 'The resident timer handler is already installed.',13,10,'$'

CODE ends
end BEGIN
```

End Listing Two

## LISTING THREE

```
-----
; Weissman/Dr. Dobbs Submission LISTING 3:
; Sample program fragment to change diskette
; BIOS parameters.
;-----

;-----
; Define the structure of the BIOS diskette parms
;-----

DISKPARMS struct

SPEC1 db ? ; Don't change these values
SPEC2 db ?
SPEC3 db ?
SPEC4 db ?
SPEC5 db ?
SPEC6 db ?
SPEC7 db ?
SPEC8 db ?
SPEC9 db ?
HEAD_SETTLE db ?
MOTOR_WAIT db ?

DISKPARMS ends

;-----
; Define the location of the pointer to the parms
;-----

SYS0 segment at 0000
org 78h

DISK_PTR label dword

SYS0 ends
```

```
-----
; Here is fragment to access the current
; parameter block, and set the settle-time
; and motor wait.
;
; Enter with the settle time in AL, and
; the motor-wait value (in 1/8ths of a sec.)
; in AH.
;
; So you can preserve and restore the current
; values, AL & AH return with them: you must
; save them for later if you want to restore.
;-----

SET_PARMS proc

push bx ; Save the reg's used.
push ds
xor bx,bx ; need sys0
mov ds,bx

assume ds:SYS0

lds bx,DISK_PTR

assume ds:nothing

xchg [bx].HEAD_SETTLE,al
xchg [bx].MOTOR_WAIT,ah

pop ds
pop bx
ret

SET_PARMS endp

;-- You need your own "assume" and "end" statements!
```

End Listing Three

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## LISTING FOUR

Timing the DOS command: "COPY B:TESTFILE.001 NUL:"

DOS200LS LOGDOS/GETSTATS (1.1) DOS timing statistics output.

Function #:	Count:	Total Time:	Mean Time:
3D	3	0:2.1970	0:0.7323 (OPEN)
3F	3	0:7.4149	0:2.4716 (READ)

Other DOS function timings not related to the test are left out

### STATISTICS SUMMARY:

Total DOS function calls counted:

83

Total DOS execution time:

0:9.7218

Mean DOS execution time:

0:0.1171

Histogram of the relevant time taken up by different functions - as before, irrelevant DOS calls left out.

3D: 22.6%\*\*\*\*\*

3F: 76.3%\*\*\*\*\*

End Listing Four

## LISTING FIVE

BASICA Interpreter with default 128-byte buffer size.

DOS200LS LOGDOS/GETSTATS (1.1) DOS timing statistics output.

Function #:	Count:	Total Time:	Mean Time:
3D	1	0:2.1970	0:2.1970 (OPEN)
3F	1153	0:41.963	0:0.0364 (READ)

### STATISTICS SUMMARY:

Total DOS function calls counted:

1171

Total DOS execution time:

0:44.215

Mean DOS execution time:

0:0.0378

(Continued on next page)

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# SPEEDING MS DOS

## LISTING FIVE (Listing continued, text begins on page 44)

3D: 05.0%\*\*\*  
3F: 94.9%\*\*\*\*\*

End Listing Five

## LISTING SIX

ASSEMBLER code calling DOS with record size of 200h bytes

DOS200LS LOGDOS/GETSTATS (1.1) DOS timing statistics output.

Function #:	Count:	Total Time:	Mean Time:
3D	1	0:1.9773	0:1.9773
3F	289	1:0.8025	0:0.2104

STATISTICS SUMMARY:

Total DOS function calls counted:  
293

Total DOS execution time:  
1:2.7798

Mean DOS execution time:  
0:0.2143

3D: 03.1%\*\*\*  
3F: 96.9%\*\*\*\*\*

End Listing Six

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## Vol. 3 1978

This volume brings together the issues which began dealing with the 6502, with mass-market machines and languages to match. The authors began speaking more in terms of technique, rather than of specific implementations; because of this, they were able to continue laying the groundwork industry would follow. These articles relate very closely to what is generally available today.  
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Systems software reached a new level with the advent of CP/M, chronicled herein by Gary Kildall and others (DDJ's all-CP/M issue sold out within weeks of publication). Software portability became a subject of greater import, and DDJ published here in full.  
Contents include: The Evolution of CP/M, a CP/M-Flavored C Interpreter, Ron Cain's C Compiler for the 8080. Further with Tiny BASIC, a Syntax-Oriented Compiler Writing Language, CP/M to UCSD Pascal File Conversion, Run-time Library for the Small-C Compiler.

## Vol. 6 1981

1981 saw our first all-FORTH issue (now sold out), along with continuing coverage of CP/M, small-C, telecommunications, and new languages. Dave Cortesi opened "Dr. Dobb's Clinic" in 1981, beginning one of the magazine's most popular features.  
Highlights: Information on PCNET, the Conference Tree, and The Electric Phone Book, writing your own compiler, systems programming language, and Tiny BASIC for the 6809.

## Vol. 7 1982

In 1982 we introduced several significant pieces of software, including the RED text editor and the Runic extensible compiler. Two new columns, The CP/M Exchange and The 16-Bit Software Toolbox, were launched, and we devoted special issues to FORTH and telecommunications. Resident Intern Dave Cortesi delivered his famous review of JRT Pascal and wrote the first serious comparison of CP/M-86 and MS-DOS. This was also the year we began looking forward to today's generation of microprocessors and operating systems, publishing software for the Motorola 68000 and the Zilog Z8000 as well as Unix code. And in December, we looked beyond, in the provocative essay, "Fifth-generation Computers."

## Vol. 8 1983

DDJ turns pro. Some of the most powerful, professional programmer's tools ever published in a magazine are in this volume. The second half of Jim Hendrix's Small C Compiler (continued from Vol. 7), Ed Ream's RED screen editor. A microcomputer subset of the Defense Department's official programming language, Ada. C and Forth and 68000 software. Because the magazine increased in size in 1983, this volume is bigger and better than ever.

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# SPEEDING MS DOS

## LISTING SEVEN (Listing continued, text begins on page 44.)

ASSEMBLER code, block read size of 0FE00h

DOS200LS LOGDOS/GETSTATS (1.1)

DOS timing statistics output.

Function #:	Count:	Total Time:	Mean Time:
3D	1	0:2.1970	0:2.1970
3F	3	0:7.1403	0:2.3801

STATISTICS SUMMARY:

Total DOS function calls counted:

7  
Total DOS execution time:  
0:9.3923

Mean DOS execution time:  
0:1.3418

3D: 23.4%\*\*\*\*\*  
3F: 76.0%\*\*\*\*\*

End Listing Seven

## LISTING EIGHT

ASSEMBLER code, block read size of 2400h ( 9 k-bytes )

DOS200LS LOGDOS/GETSTATS (1.1)

DOS timing statistics output.

Function #:	Count:	Total Time:	Mean Time:
3D	1	0:2.0322	0:2.0322
3F	17	0:9.5021	0:0.5589

STATISTICS SUMMARY:

Total DOS function calls counted:

22  
Total DOS execution time:  
0:11.534

Mean DOS execution time:  
0:0.5243

3D: 17.6%\*\*\*\*\*  
3F: 82.4%\*\*\*\*\*

End Listings

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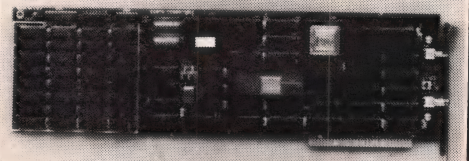
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# ASSEMBLE

## LISTING ONE (Text begins on page 122)

```

/* a square root algorithm
   04/21/85, R. A. Campbell
*/

#define NUMBER 60000

long number, ndivs, nshfts;
long sqrrt, sqrrto;

main() /* a test loop for square root calculation */
{
    nshfts = ndivs = 0;
    sqrrto = 100;
    for ( number = 0; number <= NUMBER; ++number )
    {
        sqrrt = sqrt ( number );
        /* for timing, comment out next 2 lines */
        if ( sqrrt != sqrrto )
            printf ("sqr %6d=%4d ", number, sqrrt );
        sqrrto = sqrrt;
    }
    printf ("\nTot Divs= %u Ave Divs.(x10)= %u",
            ndivs, (10 * ndivs)/NUMBER);
    printf ("\nTot Shfts= %u Ave Shfts.(x10)= %u",
            nshfts, (10 * nshfts)/NUMBER);
}

sqrt ( numb ) /* a 'rational' square root */
register long numb;
{
    register long guess1, guess2, error;
    /* return; for timing checks */
    if ( numb != 0 )
    {
        guess1 = 1;
        guess2 = numb;
        while ( (guess1 << 1) < guess2 )
        {
            guess1 <= 1; /* multiply guess1 by 2 */
            guess2 >= 1; /* divide guess2 by 2 */
            ++nshfts; /* for statistics */
        }
        do
        {
            guess1 += guess2; /* now, check */
            /* figure sum */
            guess1 >= 1; /* fig mean, divide by two */
            guess2 = numb / guess1; /* figure quotient */
            error = guess1 - guess2; /* figure error */
            ++ndivs; /* for statistics */
        } while ( error > 0 );
        return guess1;
    }
    else
        return 0;
}

```

End Listing One

## LISTING TWO

```

;SCN:v5 (C) 1985
PROGRAM
STATIC 1
Qnumber: DOUBLE
Qndivs: DOUBLE
Qnshfts: DOUBLE
Qsqrrt: DOUBLE
Qsqrrto: DOUBLE

PROGRAM
JUMP Q_shell

Qmain: PROC
VAR
BEGIN
MOVQ.D 0,R6
MOV.D R6,Qndivs
MOV.D R6,Qnshfts
MOV.D 100,Qsqrrto
MOVQ.D 0,Qnumber
Q1: CMP.D 60000,Qnumber
BLT.S Q3
Q2: MOV.D Qnumber,TOS
BSR Qsqrrt
MOV.D R6,Qsqrrt
CMP.D Qsqrrto,Qsqrrt
BEQ.S Q5
Q4: MOV.D Qsqrrt,TOS
MOV.D Qnumber,TOS
ADDR Z6,TOS
JSR Qprintf
ADJSP -8
Q5: MOV.D Qsqrrt,Qsqrrto
ADDQ.D 1,Qnumber
BR.S Q1
Q3: MOV.D 10,R6
MUL.D Qndivs,R6
QUO.D 60000,R6
MOV.D R6,TOS
MOV.D Qndivs,TOS
ADDR Z6+13,TOS
JSR Qprintf
ADJSP -8
MOV.D Qnshfts,R6
QUO.D 60000,R6

```

```

MOV.D R6,TOS
MOV.D Qnshfts,TOS
ADDR Z6+46,TOS
JSR Qprintf
ADJSP -8
ENDPROC

Z6: BYTE 115,113,114,32,37,53,100,61,37,51,100,32
      BYTE 0,10,84,111,116,32,68,105,118,115,61,37
      BYTE 51,117,32,65,118,101,32,68,105,118,115,46
      BYTE 40,120,49,48,41,61,37,50,117,0,10,84
      BYTE 111,116,32,83,104,102,116,115,61,37,51,117
      BYTE 32,65,118,101,32,83,104,102,116,115,46,61
      BYTE 37,50,117,0

```

End Listing Two

## LISTING THREE

```

Qsqrrt: PROC ;square root, dividing version
Znumb: DOUBLE ;registers R0, R6 & R7 used by compiler
VAR ;registers R1 - R5 for register variables
BEGIN <R4,R3,R2,R1,> ;push used registers
;
BR Q15 ;for timing
MOV.D Znumb,R1 ;get number into R1
CMPQ.D 0,R1 ;is number zero?
BEQ Q8 ;mustn't divide by zero
Q7: MOVQ.D 1,R2 ;guess1 = 1
MOV.D R1,R3 ;guess2 = number
Q9: MOV.D R2,R6 ;load guess1
ASH.D 1,R6 ;guess1 << 1
CMP.D R3,R6 ;compare with guess2
BLE.S Q11 ;while ( (guess1 << 1) < guess2 )
Q10: ASH.D 1,R2 ;guess1 <<= 1
ASH.D -1,R3 ;guess2 >= 1
BR.S Q9 ;see if done
Q11: ADD.D R3,R2 ;guess1 += guess2
Q13: ASH.D -1,R2 ;guess1 /= 2
MOV.D R1,R6 ;numb
QUO.D R2,R6 ;numb / guess1
MOV.D R6,R3 ;guess2 = numb / guess1
MOV.D R2,R6
SUB.D R3,R6 ;error = guess1 - guess2
MOV.D R6,R4
CMPQ.D 0,R4
BGE.S Q14 ;while ( error > 0 )
BR.S Q13
Q14: MOV.D R2,R6 ;return guess1
BR.S Q15
Q8: MOVQ.D 0,R6 ;return 0
Q16:
Q15: ENDPROC ;exit
IMPORT Q_shell 00
IMPORT Qprintf 01
END ;SCN, 03/22//85

```

End Listing Three

## LISTING FOUR

```

Qsqrrt: PROC ;square root, bit-shifting
Znumb: DOUBLE version
VAR
BEGIN
BR.S SQRTZ ;for timing
MOV.D Znumb,R0 ;number to R0
MOVQ.D 0,R1 ;estimate = 0
MOVQ.D 0,R6 ;trial root = 0
MOV.B 16,R4 ;loop count
SQRTL: ROT.D 2,R0 ;2 msb's to 2 lsb's of number
MOV.B R0,R3 ;get shifted number in R3
AND.B 3,R3 ;isolate 2 lsb's of R3
ASH.D 2,R1 ;shift estimate
OR.B R3,R1 ;OR 2 lsb's into estimate
ASH.D 1,R6 ;shift trial root
MOV.D R6,R3 ;get trial root
ASH.D 1,R3 ;trial root * 2
CMP.D R1,R3 ;compare to estimate
BLS.S SQRT2 ;need a bit?
ADDQ.D 1,R6 ;add to trial root
ADDQ.D 1,R3 ;add to estimate
SUB.D R3,R1 ;adjust estimate
SQRT2: ACB.S -1,R4,SQRTL ;count down, loop
SQRTZ: ENDPROC ;return root, in R6

```

End Listings



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# 8080 SIMULATOR

## LISTING TWO (Continued from February)

sui	move.b (pseudopc)+,d0 sub.b d0,rega move sr,d0 and.w regconff,d0 move.b 0(flagptr,d0.w),regf jmp (return)	; D6 Sui nn	subq.l #2,pseudosp lea.l \$18(targbase),pseudopc jmp (return)		
rst10	move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l \$10(targbase),pseudopc jmp (return)	; D7 Rst 10	rpo	btst #2,regf bne mloop move.b 1(pseudosp),d0 rol.w #8,d0 move.b (pseudosp),d0 addq.l #2,pseudosp lea.l 0(targbase,d0.1),pseudopc jmp (return)	; E0 Rpo
rc	btst #0,regf beq mloop move.b 1(pseudosp),d0 rol.w #8,d0 move.b (pseudosp),d0 addq.l #2,pseudosp lea.l 0(targbase,d0.1),pseudopc jmp (return)	; D8 Rc	poph	move.b (pseudosp)+,regl(regs) move.b (pseudosp)+,regh(regs) jmp (return)	; E1 Pop H
nopD9	bra illegl	; D9 Illegal for 8080	jpo	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #2,regf bne mloop lea.l 0(targbase,d0.1),pseudopc jmp (return)	; E2 Jpo addr
jc	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #0,regf beq mloop lea.l 0(targbase,d0.1),pseudopc jmp (return)	; DA Jc addr	xthl	move.b regl(regs),d0 move.b (pseudosp),regl(regs) move.b d0,(pseudosp) move.b regh(regs),d0 move.b 1(pseudosp),regh(regs) move.b d0,1(pseudosp) jmp (return)	; E3 Xthl
in	moveq #0,d0 move.b (pseudopc)+,d0 move.l #\$ff0000,a0 move.b 0(a0,d0.1),rega jmp (return)	; DB In nn	cpo	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #2,regf bne mloop move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l 0(targbase,d0.1),pseudopc jmp (return)	; E4 Cpo addr
cc	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #0,regf beq mloop move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l 0(targbase,d0.1),pseudopc jmp (return)	; DC Cc addr	pushh	move.b regh(regs),-(pseudosp) move.b regl(regs),-(pseudosp) jmp (return)	; E5 Push H
nopDD	bra illegl	; DD Illegal for 8080	ani	and.b (pseudopc)+,rega move.b rega,d0 and.w regconff,d0 move.b 16(flagptr,d0.w),regf jmp (return)	; E6 Ani nn
sbi	asr.b #1,regf move.b (pseudopc)+,d0 moveq #0,d1 subx.b d0,rega move sr,d0 and.w regconff,d0 move.b 0(flagptr,d0.w),regf jmp (return)	; DE Sbi nn	rst20	move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l \$20(targbase),pseudopc jmp (return)	; E7 Rst 20
rst18	move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp)	; DF Rst 18	rpe	btst #2,regf beq mloop move.b 1(pseudosp),d0 rol.w #8,d0	; E8 Rpe



```

move.b (pseudosp),d0
addq.l #2,pseudosp
lea.l 0(targbase,d0.l),pseudopc
jmp (return)

```

```

pch1  move.w regh(regs),d0          ; E9 Pchl
      lea.l 0(targbase,d0.l),pseudopc
      jmp (return)

```

```

jpe   move.b 1(pseudopc),d0        ; EA Jpe addr
      rol.w #8,d0
      move.b (pseudopc),d0
      addq.l #2,pseudopc
      btst #2,regf
      beq mloop
      lea.l 0(targbase,d0.l),pseudopc
      jmp (return)

```

```

xchg  move.w regd(regs),d0        ; EB Xchg
      move.w regh(regs),regd(regs)
      move.w d0,regh(regs)
      jmp (return)

```

```

cpe   move.b 1(pseudopc),d0        ; EC Cpe addr
      rol.w #8,d0
      move.b (pseudopc),d0
      addq.l #2,pseudopc
      btst #2,regf
      beq mloop
      move.l pseudopc,d1
      sub.l targbase,d1
      move.b d1,-2(pseudosp)
      rol.w #8,d1
      move.b d1,-1(pseudosp)

```

```

subq.l #2,pseudosp
lea.l 0(targbase,d0.l),pseudopc
jmp (return)

```

```


```
*preED bra illegl          ; ED Illegal for 8080
```


```

```

*   ED is a prefix for the popular Z-80 instructions. Some support
*   for them is provided by the minimal Z-80 simulation routines in
*   the next file.

```

```

xri   move.b (pseudopc)+,d0        ; EE Xri nn
      eor.b d0,rega
      move.b rega,d0
      and.w regconff,d0
      move.b 16(flagptr,d0.w),regf
      jmp (return)

```

```

rst28 move.l pseudopc,d1          ; EF Rst 28
      sub.l targbase,d1
      move.b d1,-2(pseudosp)
      rol.w #8,d1
      move.b d1,-1(pseudosp)
      subq.l #2,pseudosp
      lea.l $28(targbase),pseudopc
      jmp (return)

```

```

rp    btst #7,regf                ; F0 Rp
      bne mloop
      move.b 1(pseudosp),d0
      rol.w #8,d0
      move.b (pseudosp),d0
      addq.l #2,pseudosp

```

(Continued on next page)

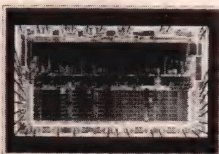
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# 8080 SIMULATOR

## LISTING TWO (Continued from February)

	lea.l 0(targbase,d0.l),pseudopc jmp (return)		move.b (pseudosp),d0 addq.l #2,pseudosp lea.l 0(targbase,d0.l),pseudopc jmp (return)		
popb	move.b (pseudosp)+,regf move.b (pseudosp)+,rega jmp (return)	; F1 Pop P	sphl	move.w regh(regs),d0 lea.l 0(targbase,d0.l),pseudosp jmp (return)	; F9 Sphl
jp	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #7,regf bne mloop lea.l 0(targbase,d0.l),pseudopc jmp (return)	; F2 Jp addr	jm	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #7,regf beq mloop lea.l 0(targbase,d0.l),pseudopc jmp (return)	; FA Jm addr
di	jmp (return)	; F3 D1	ei	jmp (return)	; FB Ei
cp	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #7,regf bne mloop move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l 0(targbase,d0.l),pseudopc jmp (return)	; F4 Cp addr	cm	move.b 1(pseudopc),d0 rol.w #8,d0 move.b (pseudopc),d0 addq.l #2,pseudopc btst #7,regf beq mloop move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l 0(targbase,d0.l),pseudopc jmp (return)	; FC Cm addr
pushb	move.b rega,-(pseudosp) move.b regf,-(pseudosp) jmp (return)	; F5 Push P	nopFD	bra illegl	; FD Illegal for 8080
oria	or.b (pseudopc)+,rega move.b rega,d0 and.w regconff,d0 move.b 16(flagptr,d0.w),regf jmp (return)	; F6 Ori nn	cpl	cmp.b (pseudopc)+,rega move sr,d0 and.w regconff,d0 move.b 0(flagptr,d0.w),regf jmp (return)	; FE Cpl nn
rst30	move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l \$30(targbase),pseudopc jmp (return)	; F7 Rst 30	rst38	move.l pseudopc,d1 sub.l targbase,d1 move.b d1,-2(pseudosp) rol.w #8,d1 move.b d1,-1(pseudosp) subq.l #2,pseudosp lea.l \$38(targbase),pseudopc jmp (return)	; FF Rst 38
rm	btst #7,regf beq mloop move.b 1(pseudosp),d0 rol.w #8,d0	; F8 Rm		.end	

End Listing Two

## LISTING THREE

```
*****
*
*   This file contains the special Z-80 simulation routines and
*   the Morrow HDC/DMA support routines.
*
*****
```

```
globl preED,outspec
xdef mloop,illegl

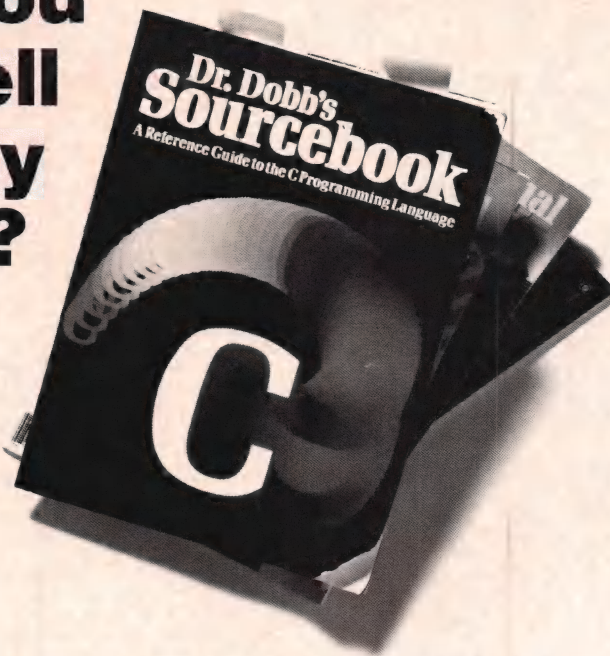
return equ @16,r      ; JMP (return) is fast return to MLOOP.
pseudopc equ @15,r    ; 8080's PC is register A5.
opptr equ @14,r       ; Pointer to opcode dispatch table.
```

(Continued on page 112)



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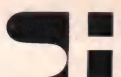
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## 8080 SIMULATOR

### LISTING THREE (Continued from February)

```
pseudosp equ @13,r      ; 8080's SP is register A3.
flagptr  equ @12,r      ; Pointer to 8080's flag lookup table is A2.
targbase equ @11,r      ; Pointer to 8080's address space is A1.
regs     equ @11,r      ; Base pointer to 8080's registers is A1.
```

```
regcon0e equ 7,r        ; Register based constant #$E (for speed).
regcon0l equ 6,r        ; Register based constant #$1.
regcon0f equ 5,r        ; Register based constant #$F.
regcondd equ 4,r        ; Register based constant #$FF.
regf      equ 3,r        ; 8080's Flags
rega      equ 2,r        ; 8080's Accumulator
```

```
regb      equ -8         ; Offsets from register base pointer for
regc      equ -7         ; 8080's pseudo-registers.
regd      equ -6         ; A & F are in Data Registers.
rege      equ -5         ; Pseudo-PC is kept in an Address Register.
regh      equ -4
regl      equ -3
regop1    equ -2         ; Operand 1 for DAA storage
regop2    equ -1         ; " 2 " " " "
```

data  
page

\*\*\*\*\*

```
*
* Opcode dispatch table. One longword entry per opcode of the
* target (Z-80) processor, including illegals.
*
```

\*\*\*\*\*

```
*
* Only a few of the most popular instructions are simulated.
* Support for the Z-80 Block move instructions is provided
* as the flags for this simulation resemble those of the Z-80
* rather than the 8080. Certain packages (notably BDS-C) check
* the flags and mistakenly assume a Z-80, then use LDIR/LDDR.
* Therefore, minimal Z-80 support is provided for these
* instructions. By no means is this a complete simulation
* of the Z-80.
*
```

\*\*\*\*\*

```
even
EDoptab dc.1 0,0,0,0,0,0,0,0 ; ED00
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED10
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED20
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED30
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED40
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED50
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED60
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED70
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED80
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; ED90
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; EDA0
dc.1 0,0,0,0,0,0,0,0
dc.1 ldir,cpir,0,0,0,0,0,0 ; EDB0
dc.1 lddr,0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; EDC0
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; EDD0
dc.1 0,0,0,0,0,0,0,0
dc.1 0,0,0,0,0,0,0,0 ; EDE0
```

(Continued on page 114)



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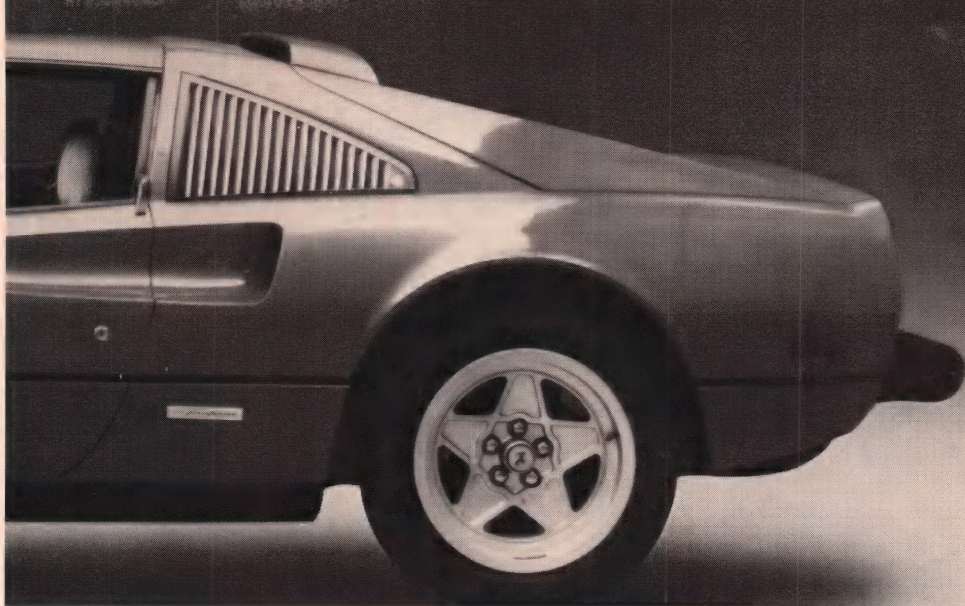
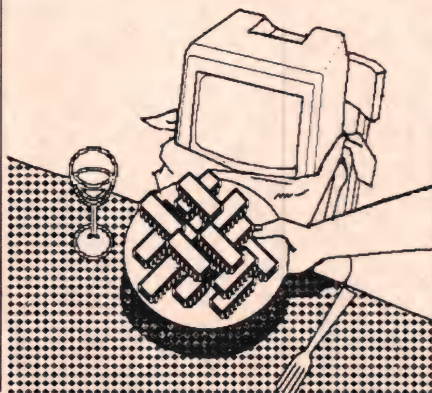
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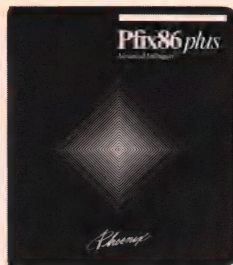
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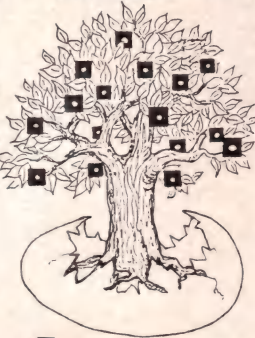
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## 8080 SIMULATOR

### LISTING THREE (Continued from February)

```

dc.l 0,0,0,0,0,0,0,0      ; EDF0
dc.l 0,0,0,0,0,0,0,0

page
text
preED moveq #0,d1          ; Zero-fill high bits.
      move.b (pseudopc)+,d1 ; Grab next opcode.
      asl #2,d1
      lea.l EDoptab,a0
      move.l 0(a0,d1.w),-(sp) ; Do the operation.
      beq illgED
      rts

illgED move.l (sp)+,d1      ; Trash the address,
      dec.l pseudopc       ; fix PPC for ILLEGAL.
      bra illegl

page
*****
*                               *
*      Z-80 opcode simulation routines.      *
*                               *
*****

ldir  move.l d2,-(sp)
      move.w regb(regs),d0 ; Grab count,
      dec.w d0             ; adjust for DBRA later.
      moveq #0,d1
      moveq #0,d2
      move.w regh(regs),d1 ; Grab source.
      move.w regd(regs),d2 ; Grab dest.
      move.l a5,-(sp)      ; Need an address reg.
      lea.l 0(targbase,d2.l),a5
      lea.l 0(targbase,d1.l),a0
ldirlop move.b (a0)+,(a5)+
      inc.w d1
      inc.w d2
      dbra d0,ldirlop
      move.l (sp)+,a5
      move.w d1,regh(regs) ; Restore result registers.
      move.w d2,regd(regs)
      move.w #0,regb(regs)
      moveq #0,regf
      move.l (sp)+,d2
      jmp (return)

lddr  move.l d2,-(sp)
      move.w regb(regs),d0 ; Grab count,
      dec.w d0             ; adjust for DBRA later.
      moveq #0,d1
      moveq #0,d2
      move.w regh(regs),d1 ; Grab source.
      move.w regd(regs),d2 ; Grab dest.
      move.l a5,-(sp)      ; Need an address reg.
      lea.l 1(targbase,d2.l),a5
      lea.l 1(targbase,d1.l),a0
lddrlop move.b -(a0),-(a5)
      dec.w d1
      dec.w d2
      dbra d0,lddrlop
      move.l (sp)+,a5
      move.w d1,regh(regs) ; Restore result registers.
      move.w d2,regd(regs)
      move.w #0,regb(regs)
      moveq #0,regf
      move.l (sp)+,d2
      jmp (return)

cpir  page
      move.w regb(regs),d0 ; Grab count,
      dec.w d0             ; adjust for DBRA later.
      moveq #0,d1

```



```

        move.w regh(regs),d1          ; Grab source.
        lea.l 0(targbase,d1.l),a0
cpirlop inc.w d1
        cmp.b (a0)+,rega
        dbeq d0,cpirlop
        seq regf
        move.w d1,regh(regs)          ; Restore result registers.
        inc.w d0
        move.w d0,regb(regs)
        tst.b regf
        bne cpir1
        moveq #0,regf                  ; Not found.
        jmp (return)
cpir1   tst d0
        beq cpir2
        moveq #$44,regf                ; Found, in the string.
        jmp (return)
cpir2   moveq #$40,regf                ; Found, but at last place.
        jmp (return)

page
*****
*                                     *
*      Output instruction simulator for Morrow HDDMA                      *
*                                     *
*****

outspec move.l d3,-(sp)
        cmp.b #$55,d0
        beq hdstart                    ; Start command? Do it,
        move.l #hdbuf,d1                ; else build first link to host buffer
        move.l #$50,a0                  ; if it's a HDRESET command.
        move.b d1,(a0)+
        ror.l #8,d1
        move.b d1,(a0)+
        ror.l #8,d1
        move.b d1,(a0)+

        move.l #$ff0000,a0              ; Do the output to HDDMA.
        adda.l d0,a0
        move.b rega,(a0)
        move.l (sp)+,d3
        jmp (return)

hdstart move.l dmalink,a0              ; Move target buffer to host buffer, do
        adda.l targbase,a0            ; all appropriate patching of addresses.
        moveq #0,d1
        move.b (a0)+,d1
        ror.l #8,d1
        move.b (a0)+,d1
        ror.l #8,d1
        move.b (a0)+,d1
        rol.l #8,d1
        rol.l #8,d1
        move.l d1,a0
        adda.l targbase,a0
        move.l a6,-(sp)
        lea.l hdbuf,a6
        move.w #3,d1
hdlloop move.b (a0)+,(a6)+
        dbra d1,hdlloop
        moveq #0,d3                    ; Fix DMA address to -> target area.
        move.b (a0)+,d3
        ror.l #8,d3
        move.b (a0)+,d3
        ror.l #8,d3
        move.b (a0)+,d3
        rol.l #8,d3
        rol.l #8,d3
        add.l targbase,d3
        move.b d3,(a6)+
        ror.l #8,d3
        move.b d3,(a6)+
        ror.l #8,d3
        move.w #5,d1                    ; Move rest of command buffer.
hdlloop2 move.b (a0)+,(a6)+
        dbra d1,hdlloop2

```

(Continued on page 118)

## MetaScope: The Debugger

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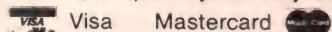
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## 8080 SIMULATOR

### LISTING THREE (Continued from February)

```

move.l #hdbuf,d1
move.b d1,(a6)+
ror.l #8,d1
move.b d1,(a6)+
ror.l #8,d1
move.b d1,(a6)+
move.l (sp)+,a6
move.l a0,-(sp)
suba.l targbase,a0
move.l a0,dmalink

move.l #fff0000,a0
adda.l d0,a0
move.b rega,(a0)

move.l #hdbuf+12,a0
hdloop3 tst.b (a0)
beq hdloop3
move.b (a0),d1
move.l (sp)+,a0
move.b d1,-(a0)
move.l (sp)+,d3
jmp (return)

data
even

dmalink dc.l $50
hdbuf ds.b 16

end

```

; Point host buffer to self.

; Save STATUS address for return val.

; Stash new target link address.

; Do the output to HDDMA.

; Wait for completion

; Fragile, but what do you want for \$1.00?

; Grab the STATUS address in target space.

; And stash status for it.

; Return to simulation.

; Storage for current HDDMA command buffer.

End Listing Three

### LISTING FOUR

```

*****
*
* This file contains the mnemonic strings for the 8080 opcodes.
* These are used in tracing.
*
*****

globl mnops

data
page
even

mnops dc.l mnop00,mnlxib,mnstaxb,mninxh,mninrb,mndcrb,mnmvib,mnrlca
dc.l mnop08,mndadb,mnldaxb,mndcxb,mninrc,mndcrb,mnmvic,mnrrca
dc.l mnop10,mnlxid,mnstaxd,mninxd,mninrd,mndcrd,mnmvid,mnrlal
dc.l mnop18,mndadd,mnldaxd,mndcxd,mninre,mndcre,mnmvie,mnrrar
dc.l mnop20,mnlxih,mnshld,mninxh,mninrh,mndcrh,mnmvih,mndaa
dc.l mnop28,mndadh,mnlhld,mndcxh,mninrl,mndcrl,mnmvil,mncma
dc.l mnop30,mnlxis,mnsta,mninxs,mninrm,mndcrm,mnmvim,mnstc
dc.l mnop38,mndads,mnlada,mndcxs,mninra,mndcra,mnmvia,mncmc
dc.l mnmovbb,mnmovbc,mnmovbd,mnmovbe,mnmovbh,mnmovbl,mnmovbm,mnmovba
dc.l mnmovcb,mnmovcc,mnmovcd,mnmovce,mnmovch,mnmovcl,mnmovcm,mnmovca
dc.l mnmovdb,mnmovdc,mnmovdd,mnmovde,mnmovdh,mnmovdl,mnmovdm,mnmovda
dc.l mnmoveb,mnmovec,mnmoved,mnmovee,mnmoveh,mnmovel,mnmovem,mnmovea
dc.l mnmovhb,mnmovhc,mnmovhd,mnmovhe,mnmovhh,mnmovhl,mnmovhm,mnmovha
dc.l mnmovlb,mnmovlc,mnmovld,mnmovle,mnmovlh,mnmovll,mnmovlm,mnmovla
dc.l mnmovmb,mnmovmc,mnmovmd,mnmovme,mnmovmh,mnmovml,mnhalt,mnmovma
dc.l mnmovab,mnmovac,mnmovad,mnmovae,mnmovah,mnmoval,mnmovam,mnmovaa
dc.l mnaddb,mnaddc,mnaddd,mnadde,mnaddh,mnaddl,mnaddm,mnaddaa
dc.l mnadcb,mnadcc,mnadcd,mnadce,mnadch,mnadcl,mnadcm,mnadca
dc.l mnsubb,mnsubb,b,mnsubb,d,mnsubb,e,mnsubb,h,mnsubb,l,mnsubb,m,mnsubb,a
dc.l mnsbbb,mnsbbb,c,mnsbbb,d,mnsbbb,e,mnsbbb,h,mnsbbb,l,mnsbbb,m,mnsbbb,a
dc.l mnandb,mnandc,mnandd,mnande,mnandh,mnandl,mnandm,mnanda
dc.l mnxrab,mnxrac,mnxrad,mnxrae,mnxrah,mnxral,mnxram,mnxraa
dc.l mnorab,mnorac,mnorad,mnorae,mnorah,mnorai,mnoram,mnoraa

```



```

dc.l mncmpb,mncmpc,mncmpd,mncmpe,mncmph,mncmpl,mncmpam,mncmpaa
dc.l mnrnz,mnpob,mnjnz,mnjpa,mncnz,mnpushb,mnadi,mnrst0
dc.l mnrz,mnret,mnjz,mnnopCB,mncz,mncall,mnaci,mnrst8
dc.l mnrnc,mnpopd,mnjnc,mnout,mncnc,mnpushd,mnsui,mnrst10
dc.l mnr,mnopD9,mnjc,mnin,mncc,mnnopDD,mnsbi,mnrst18
dc.l mnrpo,mnpoph,mnjpo,mnxthl,mncpo,mnpushh,mnani,mnrst20
dc.l mnrpe,mnpchl,mnjpe,mnxchg,mncpe,mnpred,mnxri,mnrst28
dc.l mnrp,mnpopp,mnjp,mdi,mncp,mnpushp,mnoria,mnrst30
dc.l mnr,mnsphl,mnjm,mnei,mncm,mnnopFD,mncpi,mnrst38

```

page

```

*****
*
* Mnemonic Strings. The first character flags operands.
*
* Blank is nothing, A is an address, C is a constant.
*
*****

```

```

mnop00 dc.b "NOP$"
mnlxib dc.b "ALXI B,$"
mnstaxb dc.b "STAX B$"
mninxb dc.b "INX B$"
mninrb dc.b "INR B$"
mndcrb dc.b "DCR B$"
mnmvib dc.b "CMVI B,$"
mnrlca dc.b "RLC$"
mnop08 dc.b "ILLEGAL FOR 8080$"
mndadb dc.b "DAD B$"
mnl daxb dc.b "LDAX B$"
mndcxb dc.b "DCX B$"
mninrc dc.b "INR C$"
mndcrc dc.b "DCR C$"
mnmvic dc.b "MVI C$"
mnrrca dc.b "RRC$"
mnop10 dc.b "ILLEGAL FOR 8080$"
mnlxid dc.b "ALXI D,$"
mnstaxd dc.b "STAX D$"
mninxd dc.b "INX D$"
mninrd dc.b "INR D$"
mndcrd dc.b "DCR D$"
mnmvld dc.b "CMVI D,$"
mnral dc.b "RAL$"
mnop18 dc.b "ILLEGAL FOR 8080$"
mndadd dc.b "DAD D$"
mnl daxd dc.b "LDAX D$"
mndcxd dc.b "DCX D$"
mninre dc.b "INR E$"
mndcre dc.b "DCR E$"
mnmvie dc.b "CMVI E,$"
mnrar dc.b "RAR$"
mnop20 dc.b "ILLEGAL FOR 8080$"
mnlxih dc.b "ALXI H,$"
mnshld dc.b "ASHLD $"
mninxh dc.b "INX H$"
mninrh dc.b "INR H$"
mndcrh dc.b "DCR H$"
mnmvih dc.b "CMVI H,$"
mndaa dc.b "DAA$"
mnop28 dc.b "ILLEGAL FOR 8080$"
mndadh dc.b "DAD H$"
mnlhld dc.b "ALHLD $"
mndcxh dc.b "DCX H$"
mninrl dc.b "INR L$"
mndcrl dc.b "DCR L$"
mnmvil dc.b "CMVI L,$"
mncma dc.b "CMA$"
mnop30 dc.b "ILLEGAL FOR 8080$"
mnlxis dc.b "ALXI S,$"
mnsta dc.b "ASTA $"
mninxs dc.b "INX S$"
mninrm dc.b "INR M$"
mndcrm dc.b "DCR M$"
mnmvim dc.b "CMVI M,$"
mnstc dc.b "STC$"
mnop38 dc.b "ILLEGAL FOR 8080$"
mndads dc.b "DAD S$"
mnl da dc.b "ALDA $"
mndcxs dc.b "DCX S$"
mninra dc.b "INR A$"

```

(Continued on next page)



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# 8080 SIMULATOR

## LISTING FOUR (Continued from February)

```

mndera dc.b " DCR A$"
mnnavia dc.b "CMVI A,$"
mncmc dc.b " CMC$"
mnmovbb dc.b " MOV B,B$"
mnmovbc dc.b " MOV B,C$"
mnmovbd dc.b " MOV B,D$"
mnmovbe dc.b " MOV B,E$"
mnmovbh dc.b " MOV B,H$"
mnmovbl dc.b " MOV B,L$"
mnmovbm dc.b " MOV B,M$"
mnmovba dc.b " MOV B,A$"
mnmovcb dc.b " MOV C,B$"
mnmovcc dc.b " MOV C,C$"
mnmovcd dc.b " MOV C,D$"
mnmovce dc.b " MOV C,E$"
mnmovch dc.b " MOV C,H$"
mnmovcl dc.b " MOV C,L$"
mnmovcm dc.b " MOV C,M$"
mnmovca dc.b " MOV C,A$"
mnmovdb dc.b " MOV D,B$"
mnmovdc dc.b " MOV D,C$"
mnmovdd dc.b " MOV D,D$"
mnmovde dc.b " MOV D,E$"
mnmovdh dc.b " MOV D,H$"
mnmovdl dc.b " MOV D,L$"
mnmovdm dc.b " MOV D,M$"
mnmovda dc.b " MOV D,A$"
mnmoveb dc.b " MOV E,B$"
mnmovec dc.b " MOV E,C$"
mnmoved dc.b " MOV E,D$"
mnmovee dc.b " MOV E,E$"
mnmoveh dc.b " MOV E,H$"
mnmovei dc.b " MOV E,L$"
mnmovev dc.b " MOV E,M$"
mnmovea dc.b " MOV E,A$"
mnmovhb dc.b " MOV H,B$"
mnmovhc dc.b " MOV H,C$"
mnmovhd dc.b " MOV H,D$"
mnmovhe dc.b " MOV H,E$"
mnmovhh dc.b " MOV H,H$"
mnmovhl dc.b " MOV H,L$"
mnmovhm dc.b " MOV H,M$"
mnmovha dc.b " MOV H,A$"
mnmovlb dc.b " MOV L,B$"
mnmovlc dc.b " MOV L,C$"
mnmovld dc.b " MOV L,D$"
mnmovle dc.b " MOV L,E$"
mnmovlh dc.b " MOV L,H$"
mnmovll dc.b " MOV L,L$"
mnmovlm dc.b " MOV L,M$"
mnmovla dc.b " MOV L,A$"
mnmovmb dc.b " MOV M,B$"
mnmovmc dc.b " MOV M,C$"
mnmovmd dc.b " MOV M,D$"
mnmovme dc.b " MOV M,E$"
mnmovmh dc.b " MOV M,H$"
mnmovml dc.b " MOV M,L$"
mnhalt dc.b " HLT$"
mnmovma dc.b " MOV M,A$"
mnmovab dc.b " MOV A,B$"
mnmovac dc.b " MOV A,C$"
mnmovad dc.b " MOV A,D$"
mnmovae dc.b " MOV A,E$"
mnmovah dc.b " MOV A,H$"
mnmovai dc.b " MOV A,L$"
mnmovam dc.b " MOV A,M$"
mnmovaa dc.b " MOV A,A$"
mnaddb dc.b " ADD B$"
mnaddc dc.b " ADD C$"
mnaddd dc.b " ADD D$"
mnadde dc.b " ADD E$"
mnaddh dc.b " ADD H$"
mnaddl dc.b " ADD L$"

```

```

mnaddm dc.b " ADD M$"
mnaddaa dc.b " ADD A$"
mnadcb dc.b " ADC B$"
mnadcc dc.b " ADC C$"
mnaded dc.b " ADC D$"
mnadce dc.b " ADC E$"
mnadch dc.b " ADC H$"
mnadcl dc.b " ADC L$"
mnadcm dc.b " ADC M$"
mnadca dc.b " ADC A$"
mnsubb dc.b " SUB B$"
mnsubc dc.b " SUB C$"
mnsubd dc.b " SUB D$"
mnsube dc.b " SUB E$"
mnsubh dc.b " SUB H$"
mnsubl dc.b " SUB L$"
mnsubm dc.b " SUB M$"
mnsubaa dc.b " SUB A$"
mnsubbb dc.b " SBB B$"
mnsubbc dc.b " SBB C$"
mnsubbd dc.b " SBB D$"
mnsubbe dc.b " SBB E$"
mnsubbh dc.b " SBB H$"
mnsubbl dc.b " SBB L$"
mnsubbm dc.b " SBB M$"
mnsubba dc.b " SBB A$"
mnandb dc.b " ANA B$"
mnandc dc.b " ANA C$"
mnandd dc.b " ANA D$"
mnande dc.b " ANA E$"
mnandh dc.b " ANA H$"
mnandl dc.b " ANA L$"
mnandm dc.b " ANA M$"
mnanda dc.b " ANA A$"
mnxrab dc.b " XRA B$"
mnxrac dc.b " XRA C$"
mnxrad dc.b " XRA D$"
mnxrae dc.b " XRA E$"
mnxrah dc.b " XRA H$"
mnxral dc.b " XRA L$"
mnxram dc.b " XRA M$"
mnxraa dc.b " XRA A$"
mnorab dc.b " ORA B$"
mnorac dc.b " ORA C$"
mnorad dc.b " ORA D$"
mnorae dc.b " ORA E$"
mnorah dc.b " ORA H$"
mnoral dc.b " ORA L$"
mnoram dc.b " ORA M$"
mnoraa dc.b " ORA A$"
mncompb dc.b " CMP B$"
mncompc dc.b " CMP C$"
mncompd dc.b " CMP D$"
mncmpe dc.b " CMP E$"
mncmph dc.b " CMP H$"
mncmpl dc.b " CMP L$"
mncompam dc.b " CMP M$"
mncompaa dc.b " CMP A$"
mnrnz dc.b " RNZ$"
mnret dc.b " RET$"
mnpopb dc.b " POP B$"
mnjnz dc.b "AJNZ $"
mnjmpa dc.b "AJMP $"
mncnz dc.b "ACNZ $"
mnpushb dc.b " PUSH B$"
mnadi dc.b "CADI $"
mnrst0 dc.b " RST 0$"
mnrz dc.b " RZ$"
mnjz dc.b "AJZ $"
mnnopCB dc.b " ILLEGAL FOR 8080$"
mncz dc.b "ACZ $"
mncall dc.b "ACALL $"
mnaci dc.b "CACI $"

```

```

mnrst8 dc.b " RST 8$"
mnrnc dc.b " RNC$"
mnpopd dc.b " POP D$"
mnjnc dc.b "AJNC $"
mnout dc.b "COUT $"
mncnc dc.b "ACNC $"
mnpushd dc.b " PUSH D$"
mnsui dc.b "CSUI $"
mnrst10 dc.b " RST 10$"
mnrz dc.b " RZ$"
mnnopD9 dc.b " ILLEGAL FOR 8080$"
mnjc dc.b "AJC $"
mnin dc.b "CIN $"
mnc c dc.b "ACC $"
mnnopDD dc.b " ILLEGAL FOR 8080$"
mnsbi dc.b "CSBI $"
mnrst18 dc.b " RST 18$"
mnrpo dc.b " RPO$"
mnpoph dc.b " POP H$"
mnjpo dc.b "AJPO $"
mnxthl dc.b " XTHL$"
mncpo dc.b "ACPO $"
mnpushh dc.b " PUSH H$"
mnani dc.b "CANI $"
mnrst20 dc.b " RST 20$"
mnrpe dc.b " RPE$"
mnpchl dc.b " PCHL$"
mnjpe dc.b "AJPE $"
mnxchg dc.b " XCHG$"
mncpe dc.b "ACPE $"
mnpred dc.b " ILLEGAL FOR 8080$"
mnxri dc.b "CXRI $"
mnrst28 dc.b " RST 28$"
mnrp dc.b " RPS$"
mnpopp dc.b " POP P$"
mnjp dc.b "AJP $"
mndi dc.b " DIS$"
mncp dc.b "ACP $"
mnpushp dc.b " PUSH P$"
mnoria dc.b "CORI $"
mnrst30 dc.b " RST 30$"
mnr m dc.b " RMS$"
mnsphl dc.b " SPLH$"
mnja dc.b "AJM $"
mnei dc.b " EIS$"
mncm dc.b "ACM $"
mnnopFD dc.b " ILLEGAL FOR 8080$"
mncpi dc.b "CCPI $"
mnrst38 dc.b " RST 38$"
.end

```

End Listings



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## NS32000 Square Roots

**T**he square root routine for the 68000 by Jim Cathey (16-Bit Software Toolbox, May 1985) is an example of the looping and bit-shifting routines that must be used on a microprocessor with limited arithmetic ability (i.e., 8- or 16-bit registers and only addition and subtraction). However, this kind of bit-level thinking seems unnecessary and even undesirable with a microprocessor such as the NS320XX or the 68000. A programmer would be better off attacking such problems as computing square roots from a higher level.

The NS320XX group is made by National Semiconductor (my NS16032 was an earlier version) and the 68000 by Motorola. They can perform 8-, 16-, and 32-bit addition, subtraction, multiplication, division, and modulo operations on data in registers and memory. The NS320XX, in particular, was clearly designed with high-level language compilation in mind. Although it does have bit-level capabilities, it actually performs better at a higher level.

I have described a routine for calculating square roots and have presented it in both C-language program form (Listing One, page 106) and assembly language for the NS320XX processor (Listing Two, page 106). Compiling, assembling, and linking takes about 1½ minutes on a system with relatively slow floppy-disk access. I hope that one of these presentations will be helpful to you. I often find it frustrating to try to understand an interesting programming approach to a problem when it is only general-

ber and, of course, the square of the square root equals the number. When dealing with integers, however, the situation is somewhat different. The square root of an integer is the smallest of the two most nearly equal factors of that number. For example, the two most nearly equal integer factors of 255 are 15 and 17, and the square root of 255 is 15. The integer square root when squared may not equal the number.

This routine has two stages. The first is to find two roughly equal factors of the number, *guess1* and *guess2*, in the quickest possible way. Initially, *guess1* is set to 1 and *guess2* is set to the number for which the square is desired. *Guess1* is then multiplied and *guess2* is divided by two until their values are approximately equal. An average of the two guesses is calculated as the trial square root, and we move to the testing stage. In all cases, multiplication and division by two are done by the faster methods of left and right shifting.

This trial square root now becomes *guess1* and is tested by dividing it into the number, and the quotient becomes *guess2*. An error term is calculated by subtracting *guess2* from *guess1*. If this error is negative or zero, *guess1* is taken as the square root. If this error is positive (the trial square root is too high), a new trial square root (the mean of the two guesses) is computed, and the above division test is repeated until the error becomes zero or negative.

The trial square root from the factoring stage is biased high, which is advantageous because it leads to downward adjustment only of the trial square root. This is good because when the correct square root of an integer number is divided into the number it may yield a quotient greater than the square root. For example, consider the integer square root of 24. [The first trial square root would be 5 (the mean of 4 and 6), 24 divided

by 5 is 4, because the error (5-4) is +1, 4 is not the correct root.] The next trial square root would be 5 plus 4 divided by 2, or 4. Because 24 divided by 4 equals 5, an error of -1, the integer square root of 24 is 4.

Although you might be suspicious of it, the above description should make sense, particularly if you try it out with paper and pencil. Though the bit-shifting routines are virtually opaque, this routine does work accurately and fast.

Test runs computing the square root of integers from 0 to 60,000, as shown in Listing Three, page 106, indicate that on the average 7.0 shifts (excluding the test) and 1.8 divisions per square root were carried out; 25 percent of the times only one division was required, and the maximum was four. Running the full 60,000 square root program on a 6-MHz NS16032 CPU took 27 seconds and 17 seconds without printing or counting shifts and divisions. The program only prints the square root when it changes from the previously calculated one.

Running the program without printing, counting, or square root calculations took 6 seconds; therefore, the 60,000 square roots took 11 seconds (17-6) to calculate. Thus, the average time per square root is a rather respectable 183 microseconds. The assembly-language routine was compiled and could be hand optimized. A couple of branches could be eliminated and the error term would not have to be stored. Is it worth the programming time? Not to me.

Listing Four, page 106, shows Cathey's bit-shifting version as coded for the NS320XX. Although it contains fewer instructions, it actually is considerably slower than the dividing routine. When timed in the same fashion as the shift and divide routine, it takes an average of 413 microseconds.

I believe that the NS320XX is the

---

by Richard A. Campbell

---

ly described or when it is presented in a language I am vaguely familiar with.

The square root of a real number is one of two equal factors of that num-



most powerful microprocessor around. Its generally symmetrical instruction set and many addressing modes make it relatively easy to write systems software for. After all, there is more to programming than calculating square roots! But its apparently poor showing for the bit-shifting routine, relative to the M68000 (413 vs. 200 to 250 microseconds), deserves some comments. If my two-year-old NS16032 were running 8 MHz, then the difference would be somewhat less (310 vs. 200 to 250 microseconds). Also, the M68000 times were estimated from instruction-execution clock cycles, not with an actual test program; calculating instruction-execution times "in vivo" for sophisticated microprocessors such as the NS320XX or the M68000 is not an easy task.

In any event, this short test and bit-shifting algorithm does hit the NS320XX below the belt in two ways. First, the NS320XX has a single look-ahead instruction queue that may actually cost time when executing short loops or frequent branches; this short, 14-instruction routine has to loop 16 times and may branch up to 16 times. Second, it does not have a simple bit-setting instruction for the efficient movement of single bits from a data or flag register to another register. The first problem is probably inherent in its design, but the second is a less serious design or documentation oversight.

This little exercise has further convinced me that you are better off programming at a level where the logic of a program is evident. This is particularly true with a modern microprocessor such as the NS320XX. I would urge anyone working with such a microprocessor to forget about the bit-level tricks necessary with 8-bit processors and take a fresh and rational approach to programming.

DDJ

(Listings begin on page 106.)

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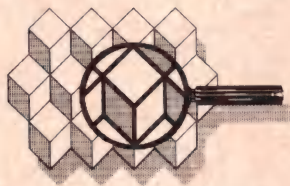


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## OF INTEREST



To write a program of moderate size that works as soon as it's compiled is a programming feat. Programmers understand the need for debugging tools in the same way that an engineer understands the need for an oscilloscope. Unfortunately, programmers generally have available only the most rudimentary debugging facilities.

To help programmers out of the morass of loads, stores, jumps, and bit-fiddling, Meridian Software Systems has developed an interactive system-independent source-level debugger for use with its Pascal compiler. It supports conditional breakpoints, subprogram traces, single-stepping, and full Pascal variable reference syntax.

TurboRef, a software tool package for Pascal users, is available from Graccon Services. TurboRef lists each variable and constant reference in a user's program. The list includes the line number and type of use for each reference. It can read multiple source files and process "include" files. A program listing can also be created. The product runs on an IBM PC with 128K memory and requires PC DOS 2.00. The price is \$49.95.

The SPS C/Atlas compilation system from Software Products & Services is modularized to enable the installation of a total system or only those elements that are needed to round

out or upgrade an existing capability. The system consists of a front-end compiler, syntax-oriented editor, code-generator compiler, TDL processor, adaptation list generator, device and switch allocation system, test and debug package, and consistency checker.

ProMod, an integrated systems engineering environment from Promod Inc., supports the complete software life cycle on PCs as well as minicomputer systems. Versions are available for IBM PCs having 512K of memory and 10-Mb hard-disk storage and DEC VAX systems operating under VMS.

Version 1.0 of P-TRAL is a language translator that enables programmers to convert Applesoft BASIC programs to Pascal. It reads the BASIC source program from disk and generates the equivalent Pascal source code. System requirements include: 64K to 128K memory, 80-column display, two disk drives, and Apple DOS 3.3/Apple Pascal 1.1, 1.2, 1.3. P-TRAL is available from Woodchuck Industries.

Cipherlink Corp. has introduced Calculations Peripheral, a software package that, when used with Any bridge software, translates data between incompatible computers. The Any data bridge resides on an independent computer connected to the source and target computers through a terminal port. It acts as a bridge between applications, extracting a desired data field from a source application, transferring it to an intermediate database, and then automatically rekeying the data into the appropriate field in the target ap-

plications. Calculations Peripheral will run on any PC DOS or Unix-based computer.

A three-part software package for analyzing and managing the IBM PC Network is available from Bickley Utilities. Net Set prompts the user interactively for information concerning the network and generates definitions for the complex parameters involved in the Net Start command. Net Stat is the on-line network statistics-gathering module.

The Omni 64 from Oliver Advanced Engineering is plug-compatible with over 300 computers and operating systems. It has 65,536 bytes of RAM, expandable to 262,144 bytes, and an unlimited firmware database. The product comes with eight logical buffers that can be configured to a different depth (to 256K words) and width (to 64 bits) to correspond with up to eight different programmable devices. The Omni 64 uses a 6-MHz 280B processor to synchronize the processor to the waveforms being produced.

The Local Applications Bus, LAB 40, is a microcomputer-to-peripheral interface and a hardware development system available from Computer Continuum. LAB 40 is a structured parallel port that takes 16K memory or I/O locations in the host computer. It can drive up to 64 8-bit input ports and 64 8-bit output ports.

AT SpeedFixer is a software utility package, available from Dynamical Systems. It features a memory-resident disk utility designed to prevent floppy disk drive errors and a keyboard utility that

increases the speed. The price is \$24.95.

C. Itoh Products has introduced two high-resolution RGB monitors. The CM1000 features both composite and RGB capability and a full-range audio speaker. In composite mode, it provides a 320 × 240 resolution with a 4-MHz bandwidth; in RGB, the resolution jumps to 640 × 240 with a 15-MHz bandwidth. The CM2000 features a nonglare black screen and is designed to be plug-compatible with the IBM PC, XT, and AT as well as the Apple IIe series.

A four-channel Multibus single-board computer designed for sophisticated data communication processing is available from SBE Inc. The COM-4 has two 10-MHz user-programmable DMA controllers that provide each of the four on-board serial ports with two channels of DMA. These channels transmit and receive blocks of data to and from on-board RAM memory. The on-board memory is dual-ported, allowing data to be accessed from either the local bus or Multibus.

Communication Machinery Corp. has announced the ENP-60, a high-performance intelligent front-end processor on a single board. The board runs the communication protocols required for the IBM PC/AT to communicate to other devices on Ethernet. The ENP-60 also runs TCP/IP software as well as the Fusion higher-level protocol software for XNS. MS DOS and Xenix are also supported.

A Virtual RAM (VRAM) card, designed to increase the capabilities and performance of the Waterloo Port Network Operating Sys-



tem, is available from Waterloo Microsystems. Equipped with a VRAM card, a port workstation can run 640K DOS applications, concurrently access network services, send mail, and perform terminal emulation and other multitasking applications. The VRAM card is a full-length board with 512K of RAM, expandable to 1 Mb. It operates with the IBM PC, XT, AT, and compatibles at speeds up to 8 MHz. The price is \$695 (\$995 in Canada).

The GL Serial Card from Microtek provides a two-way serial interface to allow the IBM PC/XT to communicate with a variety of serial peripheral devices. It is functionally equivalent to the IBM asynchronous communication adapter and supports all software designed to run with this

card on the IBM PC/XT.

Quepro Version 1.5, enables managers to analyze data files using programs such as Lotus 1-2-3, dBASE III, and MailMerge. Available from Bytel Corp., the new version permits users to generate ad hoc queries and reports without the need for programmer assistance. It can be used as is with files generated using the Cogen COBOL program generator or customized by the developer of any COBOL program. Version 1.5 is priced at \$595 for MS DOS systems, \$785 to \$1,550 for most Unix-based systems, and \$1,550 to \$9,500 for NCR and large Unix systems.

Ampère has developed a 68000-based portable computer called the WS-1. It includes up to 512K of RAM, an 80-character-25-line LCD

(200 × 480 = dot bit-mapped graphics also supported), built-in speaker phone, auto-dial 300-baud modem, programmable voice/data microcassette, two RS-232 ports, and disk I/O extension bus. WS-1 also uses a multitasking operating system called BIG.DOX. WS-1 is available from Workspace Computer.

Boston Business Computing has introduced the PC/EDT, a PC implementation of BAX EDT, the de facto Digital mainframe editor. It features multiple buffers, undelete, keyboard redefinition, command macros, multiple file access, cut and paste, screen and/or keyboard command modes, command files, and environmental variables. It supports DOS 2.0 and above as well as the full DOS directory struc-

ture. The program, priced at \$220, requires a single disk drive and 128K memory.

A down-size 201C modem that fits under a standard telephone is available from Emerald Technology Group. The 201C features digital signal processing under microprocessor control. It is designed for use on switched lines and includes circuitry for auto-answer operation. The modem, priced at \$685, also incorporates several diagnostic test functions including loopback, random-bit test patterns, and self-test.

Turn-On is an intelligent power controller from Dynatech that provides unattended remote access plus power protection. It features automatic log-on three-phase security: user

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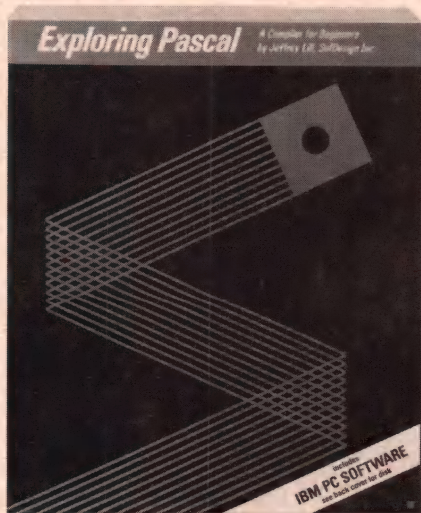
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## OF INTEREST

(Continued from page 125)

ID, password protection, and optional dial-back confirmation.

### IBM PC

The ConCur 400, an advanced adapter board that transforms single-user programs into multiterminal programs, is available from Vaxon. The board provides noninterlaced video for flicker-free display and 720 × 348 monochrome high-resolution graphics with an IBM monitor or 640 × 400 with a Princeton SR-12 or compatible monitor. It runs on the IBM PC, XT, AT, and compatibles.

Expert Edge is an expert system builder that can be used to develop interactive knowledge-based programs for the IBM PC. It uses a deductive reasoning (backward chaining) inference engine to generate expert advice or to solve a problem requiring expert knowledge. Starting from rules entered by the expert, Expert Edge builds an interactive program, called an advisor, that can then be referred to by any PC user. These rules can incorporate calculations, equations, logical reasoning, judgment, facts, and uncertainties. Features such as "True" and "Why" can follow the chain of logic being used forward or backward as well as show the builder exactly how any conclusion has been reached. The package is available from Human Edge Software and sells for \$795.

A software library of more than 8,800 IBM PC programs on a single CD-ROM disk is available from Reference Technology. It includes a selection of word processors, editors, database management sys-

tems, spreadsheets, financial and business applications, communication programs, math/statistical packages, education and music programs, and games. The price is \$850.

The Coretape system, a tape backup for the IBM PC, XT, AT, and compatibles, comes in both external and internal versions. Each offers 60 Mb of data storage. Coretape's data transfer rate is 90,000 bytes per second with the tape streaming at 90 inches per second. The system is available from CORE International.

UX Software created UX-Basic to service the IBM PC and compatibles running either the PC DOS or MS DOS operating systems. UX-Basic is compatible with the earlier model, Version 2.0. Among its features are structured code; modular programming; and sequential, direct, and ISAM files.

LDR Systems ISONET package provides independent implementation of ISO standards for open systems interconnection. The package can interconnect local area networks using X.25 protocols. It is available for the IBM PC and a number of compatibles including the Olivetti M24 and the Ericsson PC. It also runs on the Burroughs B20 range, the DEC VAX-II, the ACT Apricot, and Sirvius.

The Capture image digitizer board for IBM PC, XT, AT, and compatibles is available from Genoa Systems Corp. The board allows users to capture an image from a standard RS-170 video input, such as a camera. The captured image frame is then stored in on-board memory. The acquired image can also be simultaneously displayed on any composite graphics or TV monitor or printed on a standard graphics printer. The bit-mapped display

supports high-screen resolution of 512 × 512 pixels. A frame memory of 256K × 8 bits allows graphics overlay, requiring an address space of only 64K.

### C, Unix, and Xenix

Computer Innovations announced a C compiler for use with Digital Equipment Corp.'s VAX systems (running under VMS) to develop ROM code for the Intel family of microprocessors. The C86 ROM-C compiler consists of a four-pass C compiler that emits Intel-8086 family object or assembler code, with code-generation options for 80186 and 80286 processors and 8087-80287 math coprocessors. Full library source code and an object module translator program are also included.

Information Processing Techniques Corp. announced revisions of two C language development tools: Tracer for C debugging and C68K C Cross Compiler for the Motorola 68000 environment. Revision 3.0 of Tracer features interactive run-time debugging. Revision 2.0 of C68K includes the 68010 and 68020 as target processors.

Unibol from Software Ireland Ltd. is a commercial programming language for Unix operating systems. It allows existing DIBOL-83 programs to run under Unix System III, System V, and those look-alikes supporting the full range of system calls and providing the C standard I/O library. The package consists of a compiler, a run-time interpreter, a symbolic debugger, and a library of external utility subroutines.

UniPress Software announced software products for the IBM PC/AT running the Xenix operating

system. Uniplex II's integrated office automation package offers word processing, spreadsheet, and relational database facilities. Softkeys display available editing options in all the components. UniPress EMACS is a multiwindow full-screen editor that includes high-level programming aids and is extensible by user-defined macros and the built-in compiler MLISP programming language. Q-Calc interfaces with the Unix environment through pipes and filters and allows users to create command scripts for spreadsheet routines.

### Reference Map

Bickley Utilities (The), 101 Tyler Ct., Ambler, PA 19002; (215) 628-3750. Reader Service Number 16.

Boston Business Computing, 360 Merrimack St., Lawrence, MA 01843; (617) 683-7920. Reader Service Number 17.

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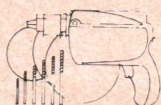
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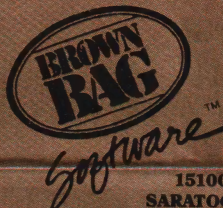
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## ADVERTISER INDEX

Reader Service No.	Advertiser	Page No.	Reader Service No.	Advertiser	Page No.
158	AMPRO Computers, Inc.	89	220	Metadigm, Inc.	115
221	Alcyon Corp.	47	110	Micro Interface Corp.	99
277	Alcyon Corp.	105	*	Micromint, Inc.	55
273	Alsys Inc.	65	105	Microprocessors Unlimited	66
121	Arity Corp.	15	*	Microsoft	67
248	Ashton-Tate	125	261	Miken Optical Co.	91
242	Ashton-Tate	27	190	Mitex	43
216	Atron	18	*	Mix Software	2
250	Austin Code Works	96	128	Morgan Computing	74
159	Blaise Computing	38	271	National Instruments	60
275	Block Island Technology	91	*	Norton Utilities (The)	43
267	Brown Bag Software	127	251	Nostradamus	123
181	C Users Group	114	137	OES Systems	89
*	C Ware	58	254	Oasys	97
246	Cardinal Point	70	124	Optotech	1
226	Cauzin Systems, Inc.	4,5	192	Overland Data Inc.	67
178	Chalcedony	39	266	Peak Electronics	93
81	Cogitate, Inc.	114	76	Personal Tex	47
237	CompuServe	C2	91	Phoenix Computer Products	C4
122	CompuView	23	139	Phoenix Computer Products	113
225	Computel Publishing Society	101	193	Plu Perfect Systems	101
96	Computer Innovations	C3	169	Poor Person Software	91
82	Creative Programming	53	229	Port A Soft	70
268	Custom Software Systems	100	*	Precise Electronics	96
265	D&W Digital	16	140	Productivity Products Int'l	41
86	Dalsoft System	70	143	Programmer's Shop	72,73
263	Data Management Consultants	69	141	Programmer's Shop	75
203	Datalight	67	264	QCAD System	100
258	Desktop AI	92	205	Queio	66
87	Digital Research Computers	83	107	Quilt Computing	66
204	Disclone	102	206	Raima Corp.	17
*	Allen Holub-Shell (House ad)	71	145	Rational Systems	128
*	C-Products (House ad)	117	*	SAS Institute Inc.	29
*	DDJ Bound Volume (House ad)	103	78	SLR Systems	61
*	DDJ Subscription (House ad)	104	114	Seidl Computer Engineering	91
*	Sourcebook (House ad)	111	85	Semi Disk Systems	92
*	280 Toolbook (House ad)	64	202	Simon & Schuster Computer Books	109
*	DDJ Mac Reprint (House ad)	113	219	Simon & Schuster Computer Books	54
*	DDJ Back Issues (House ad)	81	83	Soft Advances	105
179	Earth Computers	105	259	Soft Focus	109
89	Ecosoft, Inc.	13	113	SoftCraft, Inc.	20
90	Edward K. Ream	99	262	Software Horizons Inc.	112
138	Essential Software	42	152	Solution Systems	48
93	FairCom	61	155	Solution Systems	107
94	Fox Software	52	147	Solution Systems	77
*	GTE Government System	85	148	Solution Systems	107
*	Gimple Software	37	153	Solution Systems	48
97	Greenleaf Software	22	164	Spruce Technology Corp.	93
132	Harvard Softworks	118	172	Sunny Hill Software	88
274	Hauppauge Computer Works	63	175	TLM Systems	61
194	InfoPro Systems	74	173	TLM Systems	57
*	Integral Quality	89	174	TLM Systems	59
260	Interface Group (The)	87	230	TSF	127
257	Logitech, Inc.	19	245	Tech PC	21
98	MGlobal	34	231	Terra Base Software	95
270	Majic Software Inc.	121	234	Think Technology Inc.	35
109	Manx Software	107	77	UniPress Software	31
222	Manx Software	119	112	Wendin, Inc.	9
223	Manx Software	56	116	Wizard Systems	95
108	Manx Software	7	208	Wordtech Systems	33
102	Mark Williams	11	244	Workman & Associates	92
189	Martian Technologies	102	*	Worldwide Access Inc.	79
227	Media Cybernetics	49			

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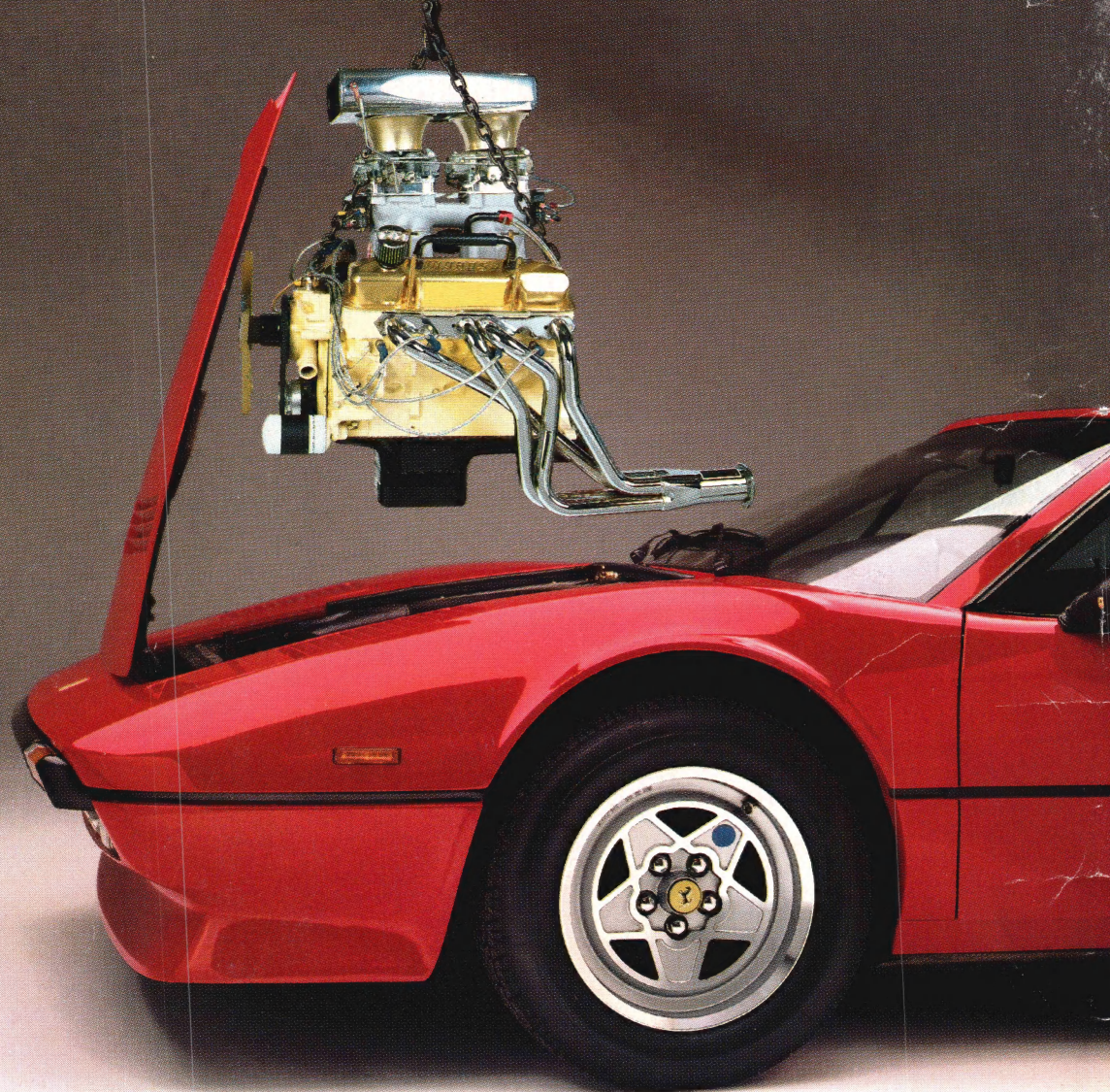
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